CHAIN-OF-CUSTODY RECORD

PHASE NO. 2016212

Sample No.	Matrix	YR:2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	VOCs	Metals	TOC	TPH	Grain Size			
BGSD101	SE	02/08	0950	Ø	5R		1	✓	✓	✓	✓	✓			-95
BGSD201	SE	02/08	0959				1	✓	✓	✓	✓	✓			-96
BGSS101	SO	02/08	1003				1	✓	✓	✓	✓				-97
DDSD201	SE	02/08	1406				1	✓	✓	✓	✓				-98
CHBSD101	SE	02/08	1425				1	✓	✓	✓	✓	✓			-99
CHBSD201	SE	02/08	1444				1	✓	✓	✓	✓	✓			-100
CHBSD301	SE	02/08	1509				1	✓	✓	✓	✓	✓			-101
CHBSD401	SE	02/08	1525				2	✓	✓	✓	✓	✓			-125
CHBSD501	SE	02/08	741540				1	✓	✓	✓	✓				-102
CHBSD601	SE	02/08	1610				1	✓	✓	✓	✓	✓			-103
DDSD101	SE	02/08	1650				2	✓	✓	✓	✓	✓ JEB 2/12/01			-126
BGSS201	SO	02/09	0855				1	✓	✓	✓	✓				-104

SAMPLE COLLECTION:

PROJECT NO. AND NAME: International Paper - Wiggins, MS 35-00009573.00
LOCATION OF SAMPLE:
TEAM LEADER: Paul Harper   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'NEAL LANE BATON ROUGE, LA 70816
WITNESS: _____ COMPANY NAME: _____

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SO)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) Standard T.O.T.
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME: Jim Rayburn	Jim Rayburn	02/09/01 1800	Carol Hins	2/9/01 1800
	COMPANY: URS	Carol Hins	2/09/01 1800		
2	NAME:	Carol Hins	2/12/01 11:00 am	Connie Chats	2/12/01 11:00
	COMPANY:	Connie Chf	2/12/01 1315		2/12/01 1315

TERMINATION OF CHAIN-OF-CUSTODY:

3°C

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 20/02/2

Sample No.	Matrix	YR: 2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	SVOC	TPH	TOC	Metals	Grain Size			
DDSD 301	SE	02/09	0913				1	✓	✓	✓					105
DDSD 401	SE	02/09	0915				2	✓	✓	✓	✓	3PH 2/14/01			127
DDSD 501	SE	02/09	0939				1	✓	✓	✓					106
BG SS 301	SO	02/09	0940				1	✓	✓	✓	✓				107
DDSD 601	SE	02/09	1003				1	✓	✓	✓					108
DDSD 701	SE	02/09	1027				1	✓	✓	✓					109
BGSS 401	SO	02/09	1035				1	✓	✓	✓	✓				110
DDSD 801	SE	02/09	1055			•	1	✓	✓	✓					111
DDSD 802	SE	02/09	1100				1	✓	✓	✓					112
SDRB 01	LI	02/09	1330				5	2	2		1				130
BGSS 501	SO	02/09	1354				1	✓	✓	✓	✓				113
DDSD 1701	SE	02/09	1404				1	✓	✓	✓					114

SAMPLE COLLECTION:

PROJECT NO. AND NAME: IP-Wiggins, MS   2500009573.00
LOCATION OF SAMPLE: _____
TEAM LEADER: Paul Harper   TELEPHONE: (225) 751-1873
COMPANY NAME: _____
ADDRESS: _____
WITNESS: _____   COMPANY NAME: _____

FIELD INFORMATION:

TYPES OF SAMPLES: (LIQUID (LI))   FISH (FI)   SLUDGE (SL)   (SOIL (SO))
(MATRIX)   WIPE (WI)   (SEDIMENT (SE))   OTHER (SPECIFY) Standard T.O.T
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

	RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
NAME: Jim Rayburn	Jim Rayburn	02/09/01 1800	Carol Hirn	2/9/01 18:00
COMPANY: URS	Carol Hirn	2/12/01 11:00 pm		2/12/01 1100
NAME:	Connie Chat	2/12/01 @ 13/5	Anna Punch	2/12/01 @ 13/5
COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

30 C

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. _____

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	SVOCs	Metals	TPH	TOC	Grain Size			
DDSD1801	SE	02/09	1412				1	√	√	√	√				115
DDSD1601	SE	02/09	1433				1	√	√	√	√				116
DDSD1301	SE	02/09	1442				1	√	√	√	√				117
DDSD1001	SE	02/09	1448				1	√	√	√	√				118
DDSD901	SE	02/09	1517				2	√	√	√	√	√ JEB 2/12/01			128
BGSSB01	SO	02/09	1535				1	√	√	√	√				119
DDSD1201	SE	02/09	1600				1	√	√	√	√				120
DDSD1101	SE	02/09	1609				2	√	√	√	√	√ JEB 2/12/01			129
BGSS701	SO	02/09	1622				1	√	√	√	√				121
DDSD1401	SE	02/09	1650				1	√	√	√	√				122
DDSD1402	SE	02/09	1655				1	√	√	√	√				123
DDSD1501	SE	02/09	1700				1	√	√	√	√				124
SDRB02	LI	02/09	1710				1	√	√	√	√				131
							5	2	2	1					

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00   IP-Wiggins, MS

LOCATION OF SAMPLE: _____

TEAM LEADER: Paul Harper

COMPANY NAME: URS   TELEPHONE: (225) 751-1873

ADDRESS: _____

WITNESS: _____   COMPANY NAME: _____

FIELD INFORMATION:

TYPES OF SAMPLES: (LIQUID (LI))   FISH (FI)   SLUDGE (SL)   (SOIL (SO))
(MATRIX)   WIPE (WI)   (SEDIMENT (SE))   OTHER (SPECIFY) Standard turn around

FIELD NOTES: _____

TRANSPORTER: _____   AIRBILL/INVOICE: _____

DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

	NAME	RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME: Jim Rayburn	Jim Ray	02/09/01 1800	Carol Hui	2/09/01 1800
	COMPANY: URS	Carol Hui	2/12/01 11:00 am	C. Chd	2/12/01 11:0
2	NAME: C. Chd	C. Chd	2/12/01 @ 1315		2/12/01 @ 1315
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____

COMPANY NAME: _____   30 C

SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010212

Sample No.	Matrix	YR: 2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	SVOC	VOC	TCLP VOA	TCLP SVOA	TCLP Metals	pH		HOLD	
EXS006	So	02/09	1540				5	"	1	4						-32
EXS007	So	02/09	1550				5	"	1	4						-33
EXS008	So	02/09	1610				5	"	1	4						-34
EXS009	So	02/09	1615				5	"	1	4						-35
EXS005	So	02/09	1517				5	"	1	4						-36
EXS010	So	02/09	1610				5	"	1	4						-37
EXS004	So	02/09	1510				5	"	1	4						-38
EXS003	So	02/09	1445				5	"	1	4						-39
SP1	So	02/09	1625				5	"	1	4						-40
SP2	So	02/09	1630				1	"	1	4		✓	✓	✓	✓	-13

per Les Brewer see attached email JEB 2/20/01   2/20/01

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35-00009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: Wiggins, MS
TEAM LEADER: Les Brewer   TELEPHONE: (225) 751-1873
COMPANY NAME: Premier
ADDRESS: 1300 Papey Way   Marina del Ray, CA
WITNESS: Tiffani Graves   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:		02/09/01	Richard W White	02-09-01
	COMPANY:	Premier	1635	GCAL	1630 1835
2	NAME:				
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010212

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	To	Station Location	Total No. Containers	SVOA	TPH	Metals	TOC	Full hydro carbon scan			HOLD	
GP45S007	So	02-08	1305				/								✓	1
GP45S008	So	02-08	1315				/	✓	✓	✓	✓	✓				14
GP46S001	So	02-08	1355				/	✓	✓	✓	✓	✓				16
GP46S002	So	02-08	1410				/								✓	2
GP46S003	So	02-08	1430				/								✓	3
GP46S004	So	02-08	1440				/	✓	✓	✓	✓	✓				17
GP46S009PH																
GP47S001	So	02-09	0810				/	✓	✓	✓	✓	✓				18
GP47S002	So	02-09	0820				/								✓	4
GP47S003	So	02-09	0825				/								✓	5
GP47S004	So	02-09	0830				/								✓	6
GP47S005	So	02-09	0840				/	✓	✓	✓	✓	✓				19

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 I.P. WIGGINS, MS. RFI
LOCATION OF SAMPLE: TREATMENT AREA 1 & 2
TEAM LEADER: PAUL HAMPER
COMPANY NAME: URS   TELEPHONE: (225) 751-1873
ADDRESS: 2822 ONER LANS
WITNESS: TIFFANY CRAVENS   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI) FISH (FI) SLUDGE (SL) SOIL (SO)
(MATRIX) WIPE (WI) SEDIMENT (SE) OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____ AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Hmp	02-09-01	Richard White	2-9-01
	COMPANY:	URS	1600	GCAL	1630 / 1935
2	NAME:				
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. _20/0212-_

Total Solid Sep 2/12/01

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	VOA	SVOA	Metals	TPH	TOC	Moisture/Total Content	Full scan hydrocarbon	Hold
GP48S001	SO	02-09	0930				1		✓	✓	✓	✓		✓	-22
GP48S002	SO	02-09	0935				1							✓	-7
GP48S003	SO	02-09	0945				1							✓	-8
GP48S004	SO	02-09	0950				1							✓	-9
GP48S005	SO	02-09	0955				1		✓	✓	✓	✓		✓	-23
GP48S006	SO	02-09	1000				1		✓	✓	✓	✓		✓	-24
GP49S001	SO	02-09	1020				5	3	✓	✓	✓	✓	1	✓	-25
GP49S002	SO	02-09	1025				1							✓	-10
GP49S003	SO	02-09	1035				1							✓	-11
GP49S004	SO	02-09	1040				1							✓	-12
GP49S005	SO	02-09	1050				1		✓	✓	✓	✓		✓	-21
GPRB06	LI	02-09	1235				5		✓	✓	✓	✓		✓	-43

SAMPLE COLLECTION:

PROJECT NO. AND NAME: _3500009573.00   I.P. Wiggins, MS.   RFI_
LOCATION OF SAMPLE: _Treatment Area 2_
TEAM LEADER: _Tiffani Cravens_   TELEPHONE: (225) 751-1873
COMPANY NAME: _URS_
ADDRESS: _2822 O'Neal Lane_
WITNESS: _Paul Hamper_   COMPANY NAME: _URS_

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   (SOIL (SO))
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-09-01	Richard Winchester	2-9-01
	COMPANY:	URS	1600	GCAL	1630 1835 AMW
2	NAME:				
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

V:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010212-

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	VOA	SVOA	Hydrocarbon Scan	METALS	TOC	Additional Organic	Full hydro Scan	
GP50S001	So	02-09	1325				5	3	1			1	✓		-26
GP50S002	So	02-09	1340				5	3	1			1	✓		-27
GP51S001	So	02-09	1345				5	3	✓			1	✓	3/6/01 3/2/01	-28
GP51S002	So	02-09	1355				5	3	1						-30
GP52S001	So	02-09	1405				5	3	1						-31
GP52S002	So	02-09	1410				5	3	1			1	✓	3/6/01	-29
GP53S001	So	02-09	1430				1		1	1			✓		-41
GP53S002	So	02-09	1435				1		1	1	1		✓		-42
TMP Blank	LI	02-09	—				3	3							-44

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 E.P. Wiggins RFI
LOCATION OF SAMPLE: SWMU 16 ; BACKGROUND SAMPLES
TEAM LEADER: TIFFANI CRAVENS   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'NEAL LANE BATON ROUGE LA. 70817
WITNESS: PAUL HARDEL   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SO)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: FED. EX.   AIRBILL/INVOICE: _____
DESTINATION: GULF COAST ANALYTICAL, BATON ROUGE LA.

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harp	02-09-01	Richard W. Melton	2-9-01
	COMPANY:	URS	1600	GCAL	1630 AMR 1835
2	NAME:				
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

CHAIN-OF-CUSTODY RECORD

loc & Resampling
4.26.01

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	VOA	SVOA	Hydrocarbon Scan	METALS	TOC	Monomer Content	Full hydro Scan	
GP50S001	So	02-09	1325				5	3	1				1	✓	26
GP50S002	So	02-09	1340				5	3	1				1	✓	27
GP51S001	So	02-09	1345				5	3	1				1	✓	28
GP51S002	So	02-09	1355				5	3	1					·	30
GP52S001	So	02-09	1405				5	3	1						31
GP52S002	So	02-09	1410				5	3	1				1	✓	29
GP53S001	So	02-09	1430				1			1	1	1		✓	41
GP53S002	So	02-09	1435				1			1	1	1		✓	42
TMP Blank	Li	02-09	—				3	3							44

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00   I.P. Wiggins RFI
LOCATION OF SAMPLE: SWMU 16 ; Background Samples
TEAM LEADER: Tiffani Cravens   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'Neal Lane Baton Rouge LA. 70817
WITNESS: Paul Harper   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SO)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: Fed. Ex.   AIRBILL/INVOICE: _____
DESTINATION: Gulf Coast Analytical, Baton Rouge LA.

SAMPLE TRANSFER: (Original must be retained with sample at all times)

	RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
NAME:	Paul C. Harp	02-09-01	Richard W Milton	2-9-01
COMPANY:	URS	1600	GCAL	1630 1835
NAME:				
COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

CORRECTED

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010209-

Sample No.	Matrix	YR: 2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	metal	SVOA	TPH	hydro carbon scan	TOC	VOA	HOLD	
GP39S001	So	02/07	1240				1				1				-26
GP39S002	So	02/07	1245				1				1				-27
GP40S001	So	02/07	1250				1	✓	✓	✓	1	✓			-28
GP40S002	So	02/07	1300				1	✓	✓	✓	1	✓			-29
GPRB04	Li	02/07	1220				5	1	2	2					-55
GP41S001	So	02/07	1315				1				1				-30
GP41S002	So	02/07	1325				1				1				-31
GP42S001	So	02/07	1455				1				1				-32
GP42S002	So	02/07	1505				1							1	-45
GP42S003	So	02/07	1515				1	1	1	1	1			1	-53
GP42S004	So	02/07	1520				1			✓	SSB 2/30			1	-34
GP42S005	So	02/07	1530				1	1	1	1		1			-46

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35-60009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: Wiggins, MS
TEAM LEADER: Paul Harper
COMPANY NAME: URS   TELEPHONE: (225) 751-1873
ADDRESS: 2822 O'Neal Lane Baton Rouge LA 70816
WITNESS: Tiffani Cravens   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:		2/8/01 @ 1130		
	COMPANY:	URS			
2	NAME:	Fed Ex # 813978555508 @	2/9/01 0905	Cuena Luda	@ 2/9/01 0905
	COMPANY:			GCAL	

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

:\FORMS\CHAIN-OF-CUSTODY.DOC

Premier Env. 14355 / 20018908 / Due 2/14/01

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010209-   Full sa

Sample No.	Matrix	YR 2001 DATE MM/DD	Time	Sample Depth From	To	Station Location	Total No. Containers	TOC	VOA	metal	SVOA	TPH		HOLD
GP435001	So	02/07	1610				4	✓	3	✓	✓	✓		-50
GP435002	So	02/07	1600				1							✓ -35
GP435003	So	02/07	1635				1	✓		✓	✓	✓		-41
GP435004	So	02/07	1650				1							✓ -36
GP435005	So	02/07	1655				1							✓ -37
TRIP BLANK	Li	02/07	—				3		3					-53
GP445001	So	02/08	0855				5	✓	3&4	✓	✓	✓		-51
GP445002	So	02/08	0905				1							✓ -38
GP445003	So	02/08	0925				1							✓ -39
GP445004	So	02/08	0935				1							✓ -40
GP445005	So	02/08	0940				1	✓		✓	✓	✓		-48
GPRB05	Li	02/08	0945				5		1	2	2			-54

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35-00009573.00   IP Wiggins RFI
LOCATION OF SAMPLE: Wiggins, MS
TEAM LEADER: Paul Harper
TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'Neal Lane Baton Rouge LA 70816
WITNESS: Tiffani Cravens   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: FedEx   AIRBILL/INVOICE: _____
DESTINATION: Gulf Coast Analytical

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:		2/8/01 @ 1130		
	COMPANY:	URS			
2	NAME:	FedEx# 813978555508	2/9/01 @ 0905		2/9/01 @ 0905
	COMPANY:			GCAC	

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

/:\FORMS\CHAIN-OF-CUSTODY.DOC

4oC

Premier Env. /4355/ 20010908 / Due 2/14/01

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010209-

full sea

Sample No.	Matrix	YR: 2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	TOC	VOA	Metal	SVOA	TPH			HOLD	
GP45S001	So	02/08	1015				5	✓	4	✓	✓	✓				-58
GP45S002	So	02/08	1020				1	✓		✓	✓	✓				-49
GP45S003	So	02/08	1025				1								✓	41
GP45S004	So	02/08	1100				1								✓	42
GP45S005	So	02/08	1105				1								✓	43
GP45S006	So	02/08	1110				1								✓	44

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35-00009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: Wiggins, MS
TEAM LEADER: Paul Harper   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'Neal Lane Baton Rouge LA 70816
WITNESS: Tiffani Craven   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:		2/8/01 @1130		
	COMPANY:	URS			
2	NAME:	FedEx #813878555508	2/9/01 @ 0905	Aaron Kirk	2/9/01 @ 0905
	COMPANY:			GCAL	

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

V:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010868

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	HYDROCARBON SCAN	SVOA	Metals	TOC	TPH full scan		
* GP20S001	So	02-06	1240	0	1.5	GP-20	1	1	✓	✓	✓	✓		41
GP20S002	So	02-06	1245	5	6.5	GP-20	1	1						42
GP21S001	So	02-06	1255	0	1.5	GP-20	1	1						44
* GP21S002	So	02-06	1305	5	6.5	GP-21	1	1	✓	✓	✓	✓		55
GP22S001	So	02-06	1315	0	1.5	GP-22	1	1						46
GP22S002	So	02-06	1320	5	6.5	GP-22	1	1						47
GP23S001	So	02-06	1335	0	1.5	GP-23	1	1						48
* GP23S002	So	02-06	1345	5	6.5	GP-23	1	1	✓	✓	✓	✓		49
GP24S001	So	02-06	1400	0	1.5	GP-24	1	1						50
GP242002	So	02-06	1410	5	6.5	GP-24	1	1						51
GP25S001	So	02-06	1420	0	1.5	GP-25	1	1						52
GP25S002	So	02-06	1431	5	6.5	GP-25	1	1						53

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 I.P. WIGGINS, MS. RFI
LOCATION OF SAMPLE: TREATMENT AREA 1 AND 2
TEAM LEADER: PAUL HARPER
TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'NEAL LANE B.R. LA. 70816
WITNESS: TIFFINI CRAVENS
COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SO)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: FED. EX
AIRBILL/INVOICE: _____
DESTINATION: GULF COAST LABS

SAMPLE TRANSFER: (Original must be retained with sample at all times)

	NAME:	RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul Harper	02-07-01		
	COMPANY:	URS	113P		
2	NAME:	FedEx# 813978555463	2/8/01 0915	GCAL	2/8/01 @ 09K
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

4°C

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010208-

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	HYDROCARBON SCAN	METALS	SVOA	TOC	TPH Full scan			
GP26S001	So	02-06	1435	0	1.5	GP-26	1								54
GP26S002	So	02-06	1440	5	6.5	GP-26	1	1	✓	✓	✓	✓			55
GP27S001	So	02-06	1450	0	1.5	GP-27	1	1							56
GP27S002	So	02-06	1500	5	6.5	GP-27	1	1							57
GP28S001	So	02-06	1505	0	1.5	GP-28	1	1	✓	✓	✓	✓			58
GP28S002	So	02-06	1510	5	6.5	GP-28	1	1							59
GP28S003	So	02-06	1515	5	6.5	GP-28	1	1							60
GP29S001	So	02-06	1525	0	1.5	GP-29	1	1							61
GP29S002	So	02-06	1530	5	6.5	GP-29	1	1							82
GP30S001	So	02-06	1540	0	1.5	GP-30	1	1							103
GP30S002	So	02-06	1550	5	6.5	GP-30	1	1							64
GPBB03	Li	02-06	1615	—	—	GP-30	5	2	1	2	P.H.	✓			84

JEPS 3/8/01

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 I.P. WIGGINS MS RFI
LOCATION OF SAMPLE: TREATMENT AREA 1 AND 2
TEAM LEADER: PAUL HARPER   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'NEAL LANE B.R. LA. 70816
WITNESS: TIFFINI   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SO)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: FED. E+.   AIRBILL/INVOICE: _____
DESTINATION: GULF COAST LABS

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul Harper	02-07-01		
	COMPANY:	URS	1130		
2	NAME:	FedEx#8139785493	2/8/01 @ 0915	GCAL	2/8/01 @ 0915
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010208-

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	Hydrocarbon Scan	SVOA	metals	TOC	TPH fullscan			
GP31S001	SO	02-07	0840	0	1.5	GP-31	1	1							65
GP31S002	SO	02-07	0850	5	6.5	GP-31	1	1	✓	✓	✓	✓			66
GP32S001	SO	02-07	0900	0	1.5	GP-32	1	1							67
GP32S002	SO	02-07	0910	5	6.5	GP-32	1	1	✓	✓	✓	✓			68
GP33S001	SO	02-07	0920	0	1.5	GP-33	1	1							69
GP33S002	SO	02-07	0930	5	6.5	GP-33	1	1	✓	✓	✓	✓			70
GP34S001	SO	02-07	0940	0	1.5	GP-34	1	1							71
GP34S002	SO	02-07	0945	5	6.5	GP-34	1	1	✓	✓	✓	✓			72
GP35S001	SO	02-07	0955	0	1.5	GP-35	1	1							73
GP35S002	SO	02-07	1005	5	6.5	GP-35	1	1							74
GP36S001	SO	02-07	1010	0	1.5	GP-36	1	1							75
GP36S002	SO	02-07	1020	5	6.5	GP-36	1	1	✓	✓	✓	✓			76

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00   I.P. Wiggins Ms, RFI
LOCATION OF SAMPLE: TREATMENT AREA 1 AND 2
TEAM LEADER: PAUL HARPER
TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'NEAL LANE B.R. LA. 70816
WITNESS: TIFFINI CRAVONS
COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   (SOIL (SO))
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: FED. Ex
AIRBILL/INVOICE: _____
DESTINATION: GULF COAST LABS

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-07-01		
	COMPANY:	URS	1130		
2	NAME:	FedEx #813978555493	2/8/01 0915	[signature]	8/8/01 0915
	COMPANY:			GCAL	

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

V:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010208-

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	Hydrocarbon Scan	Metals	SV04	TOC	TPH full scan			
GP37S001	So	02-07	1025	D	1.5	GP-37	1	1							77
GP37S002	So	02-07	1030	5	6.5	GP-37	1	1							78
GP37S003	So	02-07	1035	D	1.5	GP-37	1	1							79
GP38S001	So	02-07	1045	5	6.5	GP-38	1	1							80
GP38S002	So	02-07	1055	5	6.5	GP-38	1	1	✓	✓	✓	✓			81
GPRB02	Li	2/6/01	1230				5	2	1	2	Aut 2/8/01			-85

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 I.P. Wiggins, Ms. RFI
LOCATION OF SAMPLE: Treatment Area 1 & 2
TEAM LEADER: Paul Holder
COMPANY NAME: URS   TELEPHONE: (225) 751-1873
ADDRESS: 2822 O'Neal Lane   B.R. LA. 70816
WITNESS: Tiffini Cravens   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   (SOIL (SD))
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-07-01		
	COMPANY:	URS	1130		
2	NAME:	Fed Ex# 813978555493	2/8/01 @ 0915		2/8/01 @ 0915
	COMPANY:			GCAL	

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

4oC

:\FORMS\CHAIN-OF-CUSTODY.DOC

Premier Env. /4355 / 200l0878 / Due 2/13/01

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010208

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	VOA's 2	60A's 2	DRO					
EX5001	SOIl	02/06	1429	—	~	1	5	✓	✓	✓					.93
EX5002	SOIL	02/06	1435	—	~		5	✓	✓	✓					.94

SAMPLE COLLECTION:

PROJECT NO. AND NAME: EP Wiggins Twp Plant - RFI
LOCATION OF SAMPLE: SWMU 20
TEAM LEADER: Paul Harper
COMPANY NAME: VRS   TELEPHONE: (   )
ADDRESS:
WITNESS: Lw Brewer   COMPANY NAME: Premier

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
   (MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY)
FIELD NOTES:
TRANSPORTER: AIRBILL/INVOICE:
DESTINATION:

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:		02-07-01		
	COMPANY:	Premier	11.30		
2	NAME:	FedEx# 8139 78555 493	2/8/01 @ 0915	Arun Ruch	2/8/01 @ 0915
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: DATE: TIME:
COMPANY NAME:
SAMPLE DISPOSITION: STORAGE   DISPOSAL   OTHER

F:\FORMS\CHAIN-OF-CUSTODY.DOC

4/0C

CHAIN-OF-CUSTODY RECORD

PHASE NO. _____ 2010226

Sample No.	Matrix	YR: 201 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	DRO	Full Hydrocarbon SCAN	8270 SIM	Metals	TOC			
GP1 SO01	SOIL	02/05	1115	0	1.5		1	✓							—47
* GP1 SO02			1125	5	6.5		1	✓	✓	✓	✓	✓			48
GP2 SO01			1250	0	1.5		1	✓							49
GP2 SO02			1300	5	6.5		1	✓							50
GP3 SO01			1315	0	1.5		1	✓							51
GP3 SO02			1325	5	6.5		1	✓							52
* GP4 SO01			1330	0	1.5		1	✓	✓	✓	✓	✓			53
* GP4 SO02			1335	5	6.5		1	✓	✓	✓	✓	✓			54
GP5 SO01			1355	0	1.5		1	✓							55
GP5 SO02			1405	5	6.5		1	✓							56
GP6 SO01			1415	0	1.5		1	✓							57
* GP6 SO02	✓	✓	1420	5	6.5		1	✓	✓	✓		✓			58

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 I.P. Wiggins MS RFI
LOCATION OF SAMPLE: Treatment Area 1 and 2
TEAM LEADER: Paul Harper
COMPANY NAME: URS Corporation TELEPHONE: (   )
ADDRESS: 2822 O'NEAL Lane
WITNESS: Tiffini Cravens COMPANY NAME: URS Corporation

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI) FISH (FI) SLUDGE (SL) SOIL (SL)
(MATRIX) WIPE (WI) SEDIMENT (SE) OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____
DESTINATION: _____ AIRBILL/INVOICE: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

	NAME:	RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1		Paul C Harper	02-05-01		
	COMPANY:	URS Corporation	1800		
2	NAME:				
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

* Faxed COC to correct sample. ID's.
Original COC is attached.

CHAIN-OF-CUSTODY RECORD

PHASE NO. _____ 2010006·

Sample No.	Matrix	YR: 201 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	DRO	Full hydrocarbon SCAN	8270 SIM	Metals	TOC			
GP1 S001	SOIL	02/05	1115	0	1.5		1	✓							—47
* GP1 S002			1125	5	6.5		1	✓	✓	✓	✓	✓			48
GP2 S001			1250	0	1.5		1	✓							49
GP2 S002			1300	5	6.5		1	✓							50
GP3 S001			1315	0	1.5		1	✓							51
GP3 S002			1325	5	6.5		1	✓							52
* GP4 S001			1330	0	1.5		1	✓	✓	✓	✓	✓			53
* GP4 S002			1335	5	6.5		1	✓	✓	✓	✓	✓			54
GP5 S001			1355	0	1.5		1	✓							55
GP5 S002			1405	5	6.5		1	✓							56
GP6 S001			1415	0	1.5		1	✓							57
* GP6 S002	✓	✓	1420	5	6.5		1	✓	✓	✓	✓	✓			58

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35000 9 573.00 I.P. Wiggins MS RFI
LOCATION OF SAMPLE: Treatment Area 1 and 2
TEAM LEADER: Paul Harper
COMPANY NAME: URS Corporation   TELEPHONE: (   )
ADDRESS: 2822 O'NEAL Lane
WITNESS: Tiffini Cravens   COMPANY NAME: URS Corporation

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-05-01		
	COMPANY:	URS Corporation	1800		
2	NAME:	Fed X #813978555449	2/6/01 0905	Anna Kircher Lyn (R34) GCAL	2/6/01 0905
	COMPANY:				

4°C

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

* Faxed COC to correct sample ID's.
Original COC is attached.

CORRECTED

CHAIN-OF-CUSTODY RECORD

PHASE NO. __20106066__

Sample No.	Matrix	YR: 2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	Hydro carbon Screen (DRO)	Metals	SVOC	TPH(DRO)	Full hydrocarbon	TOC		
GP7 SO01	SOIL	02/05	1435	0	1.5		1	✓							59
* GP7SO02			1450	5	6.5		1	✓	✓	✓	✓	✓			60
GP7SO03			1440	6.5	8		1	✓							61
GP8SO01			1500	0	1.5		1	✓							62
* GP8 SO02			1510	5	6.5		1	✓	✓	✓	✓	✓			63
GP9 SO01			1515	0	1.5		1	✓							64
GP9 SO02			1525	5	6.5		1	✓							65
* GP10SO01			1535	0	1.5		1	✓	✓	✓	✓	✓			66
* GP10 SO02			1545	5	6.5		1	✓	✓	✓	✓	✓			67
GP11 SO01			1555	0	1.5		1	✓							68
GP11SO02	↓		1605	5	6.5		1	✓							69
GPRB01	Water	↓	1630	—	—		5		✓	✓	✓				70

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: Treatment Area 1 and 2
TEAM LEADER: Paul Harper
COMPANY NAME: URS Corporation   TELEPHONE: (   )
ADDRESS: 2822 Oneal Lane
WITNESS: Tiffini Cravens   COMPANY NAME: URS Corporation

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____
DESTINATION: _____ AIRBILL/INVOICE: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-05-01		
	COMPANY:	URS Corporation	1800		
2	NAME:				
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. ___20100(?e___

Sample No.	Matrix	YR: 2001 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	Hydro carbon screen (DRO)	Metals	SVOC	TPH(DRO)	Full hydrocarbons	TOC		
GP7 S001	SOIL	02/05	1455	8	1.5		1	✓							59
* GP75002			1450	5	6.5		1	✓	✓	✓		✓	✓		100
GP75003			1440	6.5	8		1	✓							101
GP8 S001			1500	0	1.5		1	✓							102
* GP8 S002			1510	5	6.5		1	✓	✓	✓		✓	✓		103
GP9 S001			1515	0	1.5		1	✓							104
GP9 S002			1525	5	6.5		1	✓							105
* GP10 S001			1535	0	1.5		1	✓	✓	✓		✓	✓		106
* GP10 S002			1545	5	6.5		1	✓	✓	✓		✓	✓		107
GP11 S001			1555	0	1.5		1	✓							68
GP11 S002	✓		1605	5	6.5		1	✓							109
GPRB 01	Water	✓	1630	—	—		5		✓	✓	✓				70

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: Treatment Area 1 and 2
TEAM LEADER: Paul Harper
COMPANY NAME: URS Corporation   TELEPHONE: ( )
ADDRESS: 2822 Oneal Lane
WITNESS: Tiffini Cravens   COMPANY NAME: URS Corporation

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-05-01		
	COMPANY:	URS Corporation	1800		
2	NAME:	FedX #813978555438	2/6/01 0905	Anna Kercher (by R34) GCAL	2/6/01 0905
	COMPANY:				

4°C

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____   DATE: _____   TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____   DISPOSAL _____   OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

CORRECTED

Premier Env. /4355 / 20010818 / Due 2/8/01

CHAIN-OF-CUSTODY RECORD

PHASE NO. 2010207

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	Hydrocarbon scan	Full hydro con/poly scan	8270	Metals	TOC			
K GP12SOO1	SO	02-06	0830	0	1.5	GP12	1	1	✓	✓	✓	✓			-28
K GP12SOO2	SO	02-06	0840	5	6.5	GP12	1	1	✓	✓	✓	✓			29
GP13SOO1	SO	02-06	0850	0	1.5	GP13	1	1							30
GP13SOO2	SO	02-06	0855	5	6.5	GP13	1	1		✓	✓	✓	✓		31
GP14SOO1	SO	02-06	0905	0	1.5	GP14	1	1		✓	✓	✓	✓		32
GP14SOO2	SO	02-06	0915	5	6.5	GP14	1	1							33
GP15SOO1	SO	02-06	0930	0	1.5	GP15	1	1							34
GP15SOO2	SO	02-06	0940	5	6.5	GP15	1	1		✓	✓	✓	✓		35
GP15SOO3	SO	02-06	0945	5	6.5	GP15	1	1							36
GP16SOO1	SO	02-06	0950	0	1.5	GP16	1	1							37
GP16SOO2	SO	02-06	1000	5	6.5	GP16	1	1							38
GP17SOO1	SO	02-06	1020	0	1.5	GP17	1	1							39

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 3500009573.00 I.P Wiggins MS RFI
LOCATION OF SAMPLE: Treatment Area 1 and 2
TEAM LEADER: Paul Harper   TELEPHONE: (225) 751-1773
COMPANY NAME: URS Corporation
ADDRESS: 2822 O'Neal Lane
WITNESS: Tiffani Cravens   COMPANY NAME: URS Corporation

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: Federal Express   AIRBILL/INVOICE: _____
DESTINATION: Gulf Coast Analytical Laboratories

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul C. Harper	02-06-00		
	COMPANY:	URS Corporation	1120		
2	NAME:	FedEx# 813978555468	2/7/01 0900	Carmen Rich	2/7/01 0900
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

4°C

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. 201020?

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	Hydrocarbon scan	Full hydro carbon scan	Metals	8270	TOC				
GP17SO02	SO	02-06	1030	5	6.5	GP17	1	1								-40
GP18SO01	SO	02-06	1050	0	1.5	GP18	1	1	✓	✓	✓	✓				-41
GP18SO02	SO	02-06	1100	5	6.5	GP18	1	1	✓	✓	✓	✓				-42
GP19SO01	SO	02-06	1105	0	1.5	GP19	1	1								-43
GP19SO02	SD	02-06	1110	5	6.5	GP19	1	1								-44

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35000D9573.00 I.P. WIGGINS, MS.   RFI
LOCATION OF SAMPLE: TREATMENT AREA 1 AND 2
TEAM LEADER: PAUL HAMPTON
TELEPHONE: (225) 751-1873
COMPANY NAME: URS CORPORATION
ADDRESS: 2822 O NEAL LANE
WITNESS: TIFFANI CRAVENS
COMPANY NAME: URS CORPORATION

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI)   FISH (FI)   SLUDGE (SL)   SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE)   OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: FEDERAL EXPRESS   AIRBILL/INVOICE: _____
DESTINATION: GULF COAST ANALYTICAL LABORATORIES

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul Hamp	02-06-01		
	COMPANY:	URS CORPORATION	1120		
2	NAME:	FedEx# 813785554	@ 2/7/01 0900	Arum Kincl	@ 2/7/01 0900
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

4°C

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

V:\FORMS\CHAIN-OF-CUSTODY.DOC

CHAIN-OF-CUSTODY RECORD

PHASE NO. _____

Sample No.	Matrix	YR: 01 DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	hydrocarbon scan							
TA2-B1 (0-1.5)	So	02-05	1115	0	1.5	TA2-B1	1	1							
TA2-B1 (5-6.5)	So	02-05	1125	5	6.5	TA2-B1	1	1							
TA2-B2 (0-1.5)	So	02-05	1250	0	1.5	TA2-B2	1	1							
TA2-B2 (5-6.5)	So	02-05	1300	5	6.5	TA2-B2	1	1							
TA2-B3 (0-1.5)	So	02-05	1315	0	1.5	TA2-B3	1	1							
TA2-B3 (5-6.5)	So	02-05	1325	5	6.5	TA2-B3	1	1							
TA2-B4 (0-1.5)	So	02-05	1330	0	1.5	TA2-B4	1	1							
TA2-B4 (5-6.5)	So	02-05	1335	5	6.5	TA2-B4	1	1							
TA2-B5 (0-1.5)	So	02-05	1355	0	1.5	TA2-B5	1	1							
TA2-B5 (5-6.5)	So	02-05	1405	5	6.5	TA2-B5	1	1							
TA2-B6 (0-1.5)	So	02-05	1415	0	1.5	TA2-B6	1	1							
TA2-B6 (5-6.5)	So	02-05	1420	5	6.5	TA2-B6	1	1							

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35-00009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: IP Wiggins MS
TEAM LEADER: Paul Harper   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'Neal Lane Baton Rouge, LA 70816
WITNESS: Tiffani Cravens   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI) FISH (FI) SLUDGE (SL) SOIL (SL)
(MATRIX) WIPE (WI) SEDIMENT (SE) OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul Hry	02-05-01 1800		
	COMPANY:				
2	NAME:	FedEx# 813918554442	2/6/01 0905	Anna Kirche GCAL	2/6/01 @ 0915
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

QoC
ADDITION

CHAIN-OF-CUSTODY RECORD

PHASE NO. _____

Sample No.	Matrix	YR:___ DATE MM/DD	Time	Sample Depth From	Sample Depth To	Station Location	Total No. Containers	hydro-carbon scan	Metals	SVOC	TPH				
TA2-B7 (0-1.5)	So	02-05	1435	0	1.5	TA2-B7	1	1							
TA2-B7 (5-6.5)	So	02-05	1450	5	6.5	TA2-B7	1	1							
TA2-B7 (6.5-8)	So	02-05	1440	6.5	8	TA2-B7	1	1							
TA2-B8 (0-1.5)	So	02-05	1500	0	1.5	TA2-B8	1	1							
TA2-B8 (5-6.5)	So	02-05	1510	5	6.5	TA2-B8	1	1							
TA2-B9 (0-1.5)	So	02-05	1515	0	1.5	TA2-B9	1	1							
TA2-B9 (5-6.5)	So	02-05	1525	5	6.5	TA2-B9	1	1							
TA2-B10 (0-1.5)	So	02-05	1535	0	1.5	TA2-B10	1	1							
TA2-B10 (5-6.5)	So	02-05	1545	5	6.5	TA2-B10	1	1							
TA2-B11 (0-1.5)	So	02-05	1555	0	1.5	TA2-B11	1	1							
TA2-B11 (5-6.5)	So	02-05	1605	5	6.5	TA2-B11	1	1							
TA2-B10-RB	Li	02-05	1630	—	—	TA2-B10	5		1	2	2				

SAMPLE COLLECTION:

PROJECT NO. AND NAME: 35-00009573.00 IP Wiggins RFI
LOCATION OF SAMPLE: IP Wiggins MS
TEAM LEADER: Paul Harper   TELEPHONE: (225) 751-1873
COMPANY NAME: URS
ADDRESS: 2822 O'Neal Lane Baton Rouge LA 70816
WITNESS: Tiffani Cravens   COMPANY NAME: URS

FIELD INFORMATION:

TYPES OF SAMPLES: LIQUID (LI) FISH (FI) SLUDGE (SL) SOIL (SL)
(MATRIX)   WIPE (WI)   SEDIMENT (SE) OTHER (SPECIFY) _____
FIELD NOTES: _____
TRANSPORTER: _____   AIRBILL/INVOICE: _____
DESTINATION: _____

SAMPLE TRANSFER: (Original must be retained with sample at all times)

		RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1	NAME:	Paul G. Harper	1800 02-05-06		
	COMPANY:	URS			
2	NAME:	Fed Ex #8(347)8553438	2/6/01 @ 0905	Anna Rush GCAL	2/6/01 @ 0905
	COMPANY:				

TERMINATION OF CHAIN-OF-CUSTODY:

AUTHORIZED BY: _____ DATE: _____ TIME: _____
COMPANY NAME: _____
SAMPLE DISPOSITION: STORAGE _____ DISPOSAL _____ OTHER _____

W:\FORMS\CHAIN-OF-CUSTODY.DOC

JDC

ADDITION

Appendix F

Sample Station Survey Results

SITE	NORTHING	EASTING	ELEVATION
GP1	424,890.06	407,263.77	248.56
GP2	424,857.09	407,241.47	246.79
GP3	424,772.18	407,322.97	248.19
GP4	424,627.86	407,389.83	248.47
GP5	424,939.12	407,168.82	245.28
GP6	424,972.96	407,203.56	246.33
GP7	425,080.23	407,134.74	244.63
GP8	425,136.76	407,140.93	244.77
GP9	425,191.78	407,126.29	244.30
GP10	425,231.60	407,193.62	245.98
GP11	425,285.43	407,490.70	242.24
GP12	425,225.51	407,435.23	243.56
GP13	425,255.91	407,427.14	242.97
GP14	425,267.78	407,394.66	243.48
GP15	425,268.36	407,355.51	243.94
GP16	425,233.68	407,531.58	242.39
GP17	425,181.99	407,562.48	242.91
GP18	425,190.42	407,523.48	243.03
GP19	425,311.69	407,426.18	242.41
GP20	425,079.56	407,513.60	248.48
GP21	425,001.50	407,551.18	248.87
GP22	424,920.34	407,603.79	248.74
GP23	424,827.16	407,651.09	248.84
GP24	424,724.02	407,700.89	248.86
GP25	424,665.43	407,643.98	249.01
GP26	424,737.17	407,607.91	249.12
GP27	424,795.70	407,580.72	248.98
GP28	424,863.32	407,548.32	249.29
GP29	424,914.27	407,524.91	249.31
GP30	424,980.65	407,498.94	249.62
GP31	425,050.46	407,446.68	249.43
GP32	425,212.03	407,322.75	246.79
GP33	425,205.37	407,240.66	246.27
GP34	425,118.56	407,216.93	247.41

SITE	NORTHING	EASTING	ELEVATION
GP35	425,113.68	407,278.66	247.76
GP36	425,043.78	407,310.63	248.54
GP37	424,991.95	407,354.33	249.24
GP38	424,940.53	407,343.98	249.42
GP39	424,870.32	407,324.50	248.76
GP40	425,131.05	407,366.12	245.74
GP41	424,725.73	407,389.32	247.98
GP42	424,928.33	407,354.17	249.32
GP43	425,122.58	407,225.26	247.64
GP44	425,133.76	407,363.26	245.71
GP45	425,247.59	407,441.58	242.58
GP45	425,268.05	407,375.89	243,72
GP47	425,187.83	407,524.50	243.11
GP48	424,910.31	407,233.05	247.67
GP49	424,971.26	407,198.54	246.19
GP50	423,609.41	408,543.79	245.46
GP51	423,599.76	408,564.37	244.98
GP52	423,581.05	408,567.59	245.41
GP53	424,054.24	408,199.02	245.98
BGSS2	425,671.24	406,638.46	231.46
BGSS3	425,119.95	406,856.90	237.98
BGSS4	424,410.51	406,979.47	228.14
BGSS5	423,493.35	407,274.14	219.03
BGSS6	423,248.98	409,245.19	247.16
BGSS7	424,216.77	408,630.24	232.46
DDSD1	425,604.77	408,251.20	199.19
DDSD3	425,630.28	406,630.10	230.52
DDSD4	425,346.18	406,603.11	221.79
DDSD5	425,010.58	406,999.88	237.83
DDSD6	425,453.09	407,246.02	234.40
DDSD7	424,493.82	407,252.45	241.53

SITE	NORTHING	EASTING	ELEVATION	
DDSD8	423,275.16	407,271.58	197.61	
DDSD9	423,093.44	409,127.56	236.07	
DDSD10	423,703.75	408,778.01	238.54	
DDSD11	423,975.13	408,743.20	232.55	
DDSD13	424,004.68	408,591.45	237.40	
DDSD14	424,518.28	408,400.29	232.27	
DDSD16	424,820.40	408,101.09	237.66	
DDSD17	423,440.23	407,739.46	231.15	
DDSD18	423,071.72	407,978. 22	227.51	
SWMU 17 EXC	423,617.30	408,537.27	244.76	
SWMU 18 EXC	423,638.82	408,480.45	245.87	
SWMU 19 EXC	423,644.98	408,619.74	242.86	WEST
SWMU 19 EXC	423,646.18	408,635.16	242.75	EAST
SWMU 20 EXC	423,098.75	408,696.94	246.71	

Appendix G

**Screening-Level Ecological
Risk Assessment**

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.1   BACKGROUND/CONTEXT

URS Corporation (URS) performed this screening-level ecological risk assessment (SLERA) in support of a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) for International Paper's (IP) treated wood products plant in Wiggins, Mississippi. The focus of the SLERA is Area of Concern (AOC) B, defined in the RFI Work Plan (Exponent 2000) as Church House Branch (CHB), a small stream northeast of the main International Paper facility. Historic releases of untreated wastewater from a creosote recovery pond and pentachlorophenol (PCP) treatment fluid are known or presumed to have reached CHB (Exponent 2000).

1.2   SCOPE/PROCESS

This SLERA generally follows the format and procedures outlined in USEPA (1997), which are consistent with the generic guidelines provided in USEPA (1998). The SLERA process entails two "steps," each of which is further subdivided as follows:

1.   Screening-Level Problem Formulation and Effects Evaluation

   - Problem Formulation - Description of the environmental setting; identification of constituents of interest (COIs); discussion of COI fate and transport; discussion of mechanisms of ecotoxicity and potential receptors; identification of complete exposure pathways; and selection of ecological endpoints. This scoping process culminates in a conceptual ecological exposure model (CEEM) of existing or potential adverse effects.

   - Effects Evaluation - Selection of ecotoxicological screening values (ESVs), or "benchmark" bulk-medium concentrations for the COIs and appropriate receptors ("endpoints").

2.   Screening-Level Exposure Estimate and Risk Characterization

   - Exposure Estimates - For the screening process, the maximum reported bulk-medium concentration of each COI is used as, or to derive, the exposure estimate.

- Risk Characterization - Comparison of exposure estimates to ESVs for the respective COIs and receptors; discussion of the implications of the results, including evaluation of uncertainties.

"Risk Characterization" is termed 'Risk Calculation' in USEPA (1997). In that guidance, results of comparisons of hypothetical exposures to "no-effects" levels are converted to ratios known as hazard quotients (HQs) and indices (HIs). Creating such ratios invites interpreting them as if they reflect a linear relationship between the magnitude of exposure and degree of response (effect), which is particularly inappropriate when "no-effects" levels are used in the comparison (i.e., as the denominator). A no-effect-based HQ exceeding unity means simply that the estimated exposure concentration is greater than the concentration selected as a level at which no response is expected (ESV). This in turn may be indicative of a potential for a response, but not necessarily that there will certainly be a response. No-effect levels may or may not reflect response thresholds. Some are merely 'the highest exposure concentration (or equivalent dose) that did not elicit an effect,' while others are statistical estimates or values extrapolated from observed effects levels by application of 'safety factors.' As discussed further in Subsection 3.2, this SLERA does not "calculate" risks. The SLERA process established in USEPA (1997) is intended to provide simple, deterministic ("pass/fail") results supportive of a conclusion that either: (1) the potential for adverse ecological effects is negligible; or (2) further investigation, usually entailing acquisition of additional information, is necessary. In the present context, this can be accomplished without the "calculation" of HQs.

2.1   PROBLEM FORMULATION

Problem formulation is a formal process for developing and evaluating hypotheses about why adverse ecological effects may occur due to the presence of site-related stressors (USEPA 1998). In this SLERA the 'stressors' are chemical constituents presumed to be residues from substances released as a result of historic activities in wood-treating and/or waste-management areas of the main International Paper - Wiggins facility[1]. The focus at the screening level is on understanding the ecological resources that could potentially be affected and recognizing the constituents that might elicit adverse effects.

2.1.1   Environmental Setting

The general environmental setting of the International Paper - Wiggins facility and AOC B is discussed in Exponent (2000) and in Section 3 of the RFI Report. A pedestrian ecological reconnaissance of Church House Branch and its riparian areas was performed by URS biologists in February 2001. Figure 1 is based on March 1996 aerial photography from the U.S. Geological Survey (USGS) and downloaded from the TerraServer website (www.terraserver.com). The area evaluated during the ecological reconnaissance is about 61 acres, consisting essentially of the slopes and "bottom" of the valley of CHB within International Paper property.

2.1.1.1 Habitats and Vegetative Communities

CHB is a small stream that originates in the southeastern portion of Wiggins and flows southward about 6 miles to join Red Creek, a major tributary of the Black Creek system of the Pascagoula River Drainage. According to USGS interpretation of historic aerial photography, CHB is a perennial ("blue-line") stream throughout most of its length (USGS 1983). However, the uppermost reach extending from about the northern International Paper property boundary to the stream's origin in Wiggins is intermittent. Despite the unusually dry weather during the preceding three years, the February 2001 ecological reconnaissance indicated that the USGS (1983) interpretation of local hydrography remains essentially valid.

---

[1] It should be recognized that Church House Branch (AOC B) has been and remains susceptible to a variety of *physical* stresses, mainly (but not entirely) attributable to anthropogenic factors independent of activities at the International Paper facility.

That is, virtually all of CHB within and downstream from International Paper property contains perennial aquatic habitat.

The aquatic habitat within AOC B consists of three semi-isolated beaver ponds, interspersed with sections of discrete or braided stream channels of varying lengths (Figure 1). Thus there is a mixture of lentic (sluggish or static) and lotic (flowing-water) water bodies that would be expected to offer a wider variety of microhabitats within the overall reach than might otherwise be present near the headwaters of a first-order stream. A relatively flat riparian terrace extends laterally to varying widths from the CHB channel, generally much narrower on the west. This "bottomland" appears to have historically supported a more or less continuous palustrine broad-leaved (hardwood) forest vegetative community along the entire reach contained within AOC B. The stream would likely have once had a closed canopy throughout the reach in question, but the combination of selective logging and beaver activity appears to have created the open areas that are clearly evident in Figure 1. Both the vegetative community structure observed during the ecological reconnaissance and the 1996 aerial photography suggest that the basic habitat mix described above has been present for at least a decade. The riparian wetlands are now a mixture of bottomland hardwood forest (shallow swamp where flooded) and emergent herbaceous communities (marshes), with some transitional strips of scrub-shrub vegetation.

Adjacent to the riparian zones on either side of CHB are forested slopes, neither of which is particularly steep except in localized areas near the crest on the western (facility) side. On the western side, the terrain descends from about 230 feet above NGVD (National Geodetic Vertical Datum; essentially equivalent to "mean sea level") in the main facility area to about 190 feet NGVD along the riparian terrace. The slope is widest (hence the least steep) at the northern end, and gradually narrows (becoming steeper) toward the south. In contrast, the slope on the northeastern side of the stream is generally more gradual to, and beyond, the property line. There is a broad swale, or secondary "valley," entering that of CHB from the east around the latitude of the southernmost beaver pond, so that (at the time of the reconnaissance) a large lobe of the pond spread east-northeastward about halfway between the CHB channel and the International Paper boundary. Another drainage pathway enters the CHB valley from near the northeast corner of the property. This conveyance is represented, within International Paper property, by the remnant of a former tributary that appears to have been artificially channelized (i.e., straightened). Not far off-site, this stream has been

dammed to create a farm pond. Two background sediment samples were collected from this tributary (Figure 1).

Because of the steeper slopes along the western (facility) side of the valley the transition between the wetland and upland vegetative communities is fairly abrupt. In contrast, a relatively broad band of seasonally or permanently (at the ponds) flooded or saturated terrain appears along the eastern side of CHB. Near the northern end of the property is a relatively pure stand of mature sweet bay, which grades with southward progression into a mixture including Tupelo gum, wax myrtle, sycamore, and water oak. The understory includes small wax myrtle, yaupon, gallberry, and small sweet bay. Toward the southern end of the CHB riparian terrace within International Paper property, there appears to have been substantial storm damage to the bottomland forest, with a high incidence (up to nearly 100 percent in some areas) of fallen canopy trees[2]. This damage may be attributable to two large storms (Frances and Georges) in autumn of 1997, or a more recent, isolated event. Most of the downed large trees appear to be within areas inundated by the beaver pond, and are of species that are intolerant of prolonged flooding and/or soil saturation. In other words, most of these trees were probably dead or moribund, due to flooding, at the time the storm(s) hit.

Although the upland slopes are entirely forested (except at various SWMUs adjacent to the main facility processing areas), the topography and apparent localized forest management practices have produced a remarkable variety of community composition and structure. This is especially true east of CHB. In general, the slopes along the western side of the valley bottom are covered by relatively pure stands of younger loblolly pine at the northern end, an intermediate-age mixed but still heavily loblolly dominated stand in the middle, and a relatively mature mixed stand (still pine-dominated) to the south. In the latter area and to some extent in the middle, a few hardwoods (mainly water and cherrybark oaks) and longleaf pines contribute to the canopy. The understory is comprised mainly of yaupon, red maple, smaller cherrybark and other oaks, southern magnolia, sweetgum, and American holly.

Along the outer edges of the riparian terrace east of CHB the bottomland/swamp forest grades into a transitional community with increasing incidence of sweetgum, blackgum (replacing Tupelo), water oak, and laurel oak. Understory in this transitional zone becomes thicker, with the addition of small sweet bay, yaupon, and titi. Farther up the slope, pines (mainly loblolly) tend to be increasingly abundant and eventually dominate the canopy.

---

[2] Not evident in 1996 aerial photography (Figure 1).

2.1.1.2 Animal Communities

The foregoing create a relatively "natural," undisturbed, and secluded corridor separating higher terrain that is largely developed for industrial, commercial, transportation-related, silvicultural, agricultural (primarily grazing), and residential uses. Although no biological sampling was performed during the reconnaissance, the limited observations indicate that the stream and beaver ponds probably support resident populations of strictly aquatic animals typical of such habitats in the region. Mosquitofish and a few small sunfish were observed in shallow, marginal, portions of the ponds. Based on the amount of emergent vegetation, periphyton, leaf litter, and other detrital material, a moderately diverse and productive benthic invertebrate community would be expected – especially in the littoral portions of the ponds, which are extensive since they encompass flooded former riparian areas.

Another objective of the ecological reconnaissance was to evaluate the potential occurrence of terrestrial and semi-aquatic (e.g., amphibious) vertebrates, or "wildlife," that might be exposed to COIs associated with CHB sediments. The upland and wetland habitats described above would be expected to support a diverse assemblage of resident and transient wildlife. The presence of various amphibians, reptiles, birds, and mammals was documented via direct visual observation and/or recognition of "sign" such as tracks, scat, skeletal or other parts (e.g., feathers), and vocalizations. Amphibians and reptiles recorded included southern cricket frogs, bullfrogs, box turtles, mud turtles, slider turtles, garter snakes, and southern black racer. Avian species included wood duck, great blue heron, red-tailed hawk, blue jays, brown thrasher, loggerhead shrike, crows, red-winged blackbirds, and numerous other common small forest, woodland, and "edge" dwelling forms (e.g., chickadees, robins, cardinals, sparrows). Had the reconnaissance been a few weeks later in the year, it is likely that a number of neotropical migrant songbirds, such as various warblers, would have been recorded. Mammals recorded in the study area included opossum, armadillos, beavers, gray squirrel, eastern cottontail (rabbit), raccoons, striped skunk, red fox, coyote, bobcat, and white-tailed deer.

Online databases and URS regional experience were considered to evaluate the potential presence of any federally listed endangered, threatened, or candidate (ETC) species. One listed plant (Louisiana quillwort) and six animals (gopher tortoise, yellow-blotched map turtle, eastern indigo snake, black pine snake, red-cockaded woodpecker, and Louisiana black

bear) are known, at least historically, to occur in Stone County. The only ETC species for which appropriate habitat might be available in the vicinity of the study area are upland forms with very specific vegetative cover requirements (gopher tortoise, indigo snake, black pine snake, red-cockaded woodpecker). None of these particular habitats were observed in AOC B.

2.1.2 Constituents of Interest (COIs)

For purposes of the SLERA, constituents of interest (COIs) include:

- All inorganic analytes detected via EPA SW-846 6000/7000 Series methods in at least one sediment sample from CHB (one metalloid and four metals);

- The hydrocarbon mixture "PHC as Diesel" (the only 'petroleum hydrocarbon' analyte detected in CHB sediments via EPA Method 8015B);

- All 17 polycyclic aromatic hydrocarbons (PAHs) in the compound list for EPA SW-846 Method 8270SIM; and

- Pentachlorophenol (PCP; the only chlorinated phenol detected in CHB sediments via EPA SW-846 Method 8270SIM).

Even though some were not detected, all individual PAH compounds are considered COIs because effects-based ESVs are available, at least for direct exposures to sediment-dwelling invertebrates, and it is possible to derive risk-based sediment concentrations to serve as ESVs for indirect (ingestion-pathway) exposures to wildlife receptors for groups of PAHs. When concentrations of individual compounds are added together to estimate exposures to groups of PAHs (i.e., low molecular weight, high molecular weight, total), certain of the non-detect compounds can be included for conservatism, as discussed in Subsection 3.1.

2.1.3 COI Fate and Transport

Migration (including bioavailability) and persistence of a COI in an aquatic environment is controlled by: (1) physicochemical properties of the constituent; (2) physicochemical attributes of the system (i.e., its limnology); and (3) the organisms and biological processes

within the system. All of these factors alter the ultimate fate of the COI, including its "toxicity," and their interaction is highly site-specific.

Other than certain anecdotal and qualitative observations made during the ecological reconnaissance and sediment sampling, there are no data available on the limnology of CHB. However, review of limited water-quality data from nearby Red Creek (online records from USGS Station 02479191 and MGFC 1979) and URS experience in the region in general suggest that CHB water is likely to be slightly acidic, poorly buffered, and very soft. Reducing conditions would be expected to prevail in the heavily organic sediments.

2.1.3.1 Inorganics

The fate and transport of the inorganic COIs is dominated by speciation or complexation. Factors such as pH, buffering capacity, hardness, alkalinity, oxidation-reduction ("redox") potential (Eh), and availability of ligands are important in determining the main form(s) that a given inorganic constituent will assume in both the solid and aqueous phases.

2.1.3.1.1   Arsenic (As)

Arsenic is a highly mobile metalloid with a fairly complex cycling regime that includes abiotic and biological factors (USEPA 1975, 1985; Eisler 1988a; D'Itri 1990; Lindsay and Sanders 1990). In many respects, the behavior of arsenic in natural aquatic systems is similar to that of phosphorus. Four oxidation states are stable in solution, given the prevailing pH and Eh: As^{+5}, As^{+3}, As, and As^{-3}. Speciation in natural waters also depends heavily on organic content, suspended solids, and dissolved oxygen levels. In aerobic waters, arsenic is generally encountered as a relatively unstable acid species (e.g., H_3AsO_4); under mildly reducing conditions, more stable species (e.g., H_3AsO_3) tend to predominate. Arsenic can form complexes with sulfides under low-pH conditions. Volatilization of arsenic generally only occurs as arsine (AsH_3), which can form in highly reduced environments. The latter is generally not believed to be a significant fate process under most environmental conditions (USEPA 1979, 1985).

Sorption of arsenic to clays, aluminum hydroxide, and organic material has a major role in the fate and transport in most aquatic systems (USEPA 1979; D'Itri 1990). Adsorption to sediments is most important in aerobic, acidic freshwaters and less so in reducing, alkaline,

and saline waters. Arsenates tend to be more strongly adsorbed onto lake sediments than other forms of arsenic, due to the interaction of anionic arsenates and hydrous iron oxides. Apparently, arsenic is incorporated *into* sediments at the time of hydrous oxide formation, rather than by adsorption onto existing surfaces (Aggett and Roberts 1986).

The bioavailability (hence toxicity) of arsenic varies substantially with the chemical form. Availability appears to conform to the following order, from highest to lowest: arsines > inorganic arsenites (As^{+3}) > organic trivalent compounds (arsenoxides) > inorganic arsenates (As^{+5}) > organic pentavalent compounds > arsonium compounds > elemental arsenic (Eisler 1988a). Although readily absorbed directly via the same active transport system normally used for phosphate, or indirectly via ingestion, arsenicals also tend to be rapidly excreted, so they do not tend to bioaccumulate or biomagnify (Lindsay and Sanders 1990).

2.1.3.1.2   Chromium (Cr)

It is widely recognized that nearly all of the chromium in sediments tends to be in the trivalent form (Cr^{+3}) (McComish and Ong 1988). Chromium can exist in variable oxidation states from Cr^{+2} to Cr^{+6}, although the highly oxidized forms are environmentally unstable. The behavior of chromium in sediments is primarily governed by pH and Eh. Under acidic conditions (pH<5, redox of 500 mV), Cr^{+2} predominates; at slightly acidic conditions (pH 5 to 7, redox of 500 mV), most chromium occurs as $Cr(OH)^3$; and under more alkaline conditions (pH >7, redox 500 mV), CrO_4^{-2} predominates. Thus, under circumneutral or slightly acidic conditions (as would be expected in CHB sediments), most chromium exists as an insoluble salt. Chromium will adsorb to clay particles, depending upon pH, and will also form organic complexes. Under normal sediment conditions, the ready conversion of Cr^{+6} to relatively insoluble Cr^{+3} results in low bioavailability to plants and animals (McComish and Ong 1988; Kabata-Pendias and Pendias 1992).

2.1.3.1.3   Copper (Cu)

Copper in natural sediments is relatively immobile; the most common mobile form is Cu^{+2}. Copper complexes effectively with both organic (humic and fulvic acids) and inorganic ligands, as well as forming stable bonds with metal oxides (McComish and Ong 1988). The solubilities of these forms, aside from the insoluble metallic oxides, are pH dependent. All soil/sediment minerals are capable of adsorbing copper from solution, the magnitude of

which is dependent upon the surface charge carried by the sorbents. Minerals with the greatest affinity for copper include iron and manganese oxides, iron and aluminum hydroxides, and some clays. Microbial fixation of copper is a key process in its ecological cycling in soils and sediments; the degree is variable and affected by copper concentration, various matrix properties, and temperature. Where sulfides are abundant, as would be expected in the sediments (and/or flooded riparian soils) of AOC B, the bioavailability of divalent metals such as copper is probably very limited (Ankley *et al.* 1996).

2.1.3.1.4   Lead (Pb)

Lead in natural sediments is predominantly associated with sulfates, clay minerals, manganese oxides, iron and aluminum hydroxides, and organic matter (D'Itri 1990). Lead is considered the least mobile of the heavy metals in solid matrices (McComish and Ong 1988; D'Itri 1990; Kabata-Pendias and Pendias 1992). It is most often found in the divalent form Pb^{+2}, in soils/sediments and interstitial ("pore") water. Where sulfides are abundant, as would be expected in the sediments (and/or flooded riparian soils) of AOC B, the bioavailability of divalent metals such as lead is probably very limited (Ankley *et al.* 1996).

2.1.3.1.5   Nickel (Ni)

Nickel tends to complex with both inorganic and organic ligands in aquatic systems. Over most of the pH range, Ni^{+2} and $NiSO_4$ are the predominant species (McComish and Ong 1988). Nickel is considered one of the more mobile of the heavy metals (Fuller 1977). The sorptive behavior of nickel in soils and sediments is poorly studied, but iron and manganese oxides, clay minerals, and (to a lesser extent) organic matter are thought to be important sorbents (McComish and Ong 1988). Nickel adsorption on iron and manganese oxides is pH-dependent, probably because $NiOH^+$ is preferentially sorbed and the surface charge on sorbents is affected by pH (Rai *et al.* 1984). Complexing legands such as SO_4^{-2} and organic acids reduce sorption. Remobilization of nickel from solid phases also appears possible in the presence of fulvic and humic acids. Hence, sorption may be a moderately effective stabilizing mechanism in natural, unpolluted systems, but may be minimal where complexation is important (e.g., organically rich, acidic, systems) (USEPA 1979). Thus, among the inorganic COIs, nickel may be the most likely to be bioavailable.

It should be noted, however, that nickel was not detected in background sediment samples; was detected only once in CHB sediments; and was seldom detected in the drainage ditch sediments (RFI Report Table 9). Moreover, where detected, nickel was at concentrations consistently lower (usually by an order of magnitude) than levels generally considered "elevated" relative to natural conditions (e.g., > 20 mg/kg; Beyer 1990; Irwin *et al.* 1997).

2.1.3.2 Petroleum Hydrocarbons

The only 'petroleum hydrocarbons' detected in CHB and background sediments was a complex mixture reported as "PHC as Diesel." Inasmuch as diesel fuel was the carrier in treatment fluids known to have been historically released, it is reasonable to conclude that this reported COI represents (in essence) residues of a weathered diesel mixture. Normal, branched, and cyclic alkanes (also known as paraffins) are the most abundant compounds found in diesel fuel (estimated 65 to 85 percent) (Irwin *et al.* 1997; Gustafson *et al.* 1997; Potter and Simmons 1998; Weisman 1998). Polycyclic aromatic hydrocarbons (PAHs) are relatively minor constituents of diesel mixtures, but those found in CHB sediments may have also come, in large part, from the diesel fuel releases (see below).

When a diesel fuel mixture is released to soil or water, its lighter (and relatively more soluble/toxic) constituents tend to volatilize and/or biodegrade fairly rapidly, while the heavier components (e.g., carbon number ≥ 10) readily partition to organic matter in soil or sediment (Irwin *et al.* 1997; Gustafson *et al.* 1997). Accordingly, for purposes of evaluating potential fate and toxicity, it is assumed that the residues reported as "PHC as Diesel" are essentially equivalent to the C_{10}-C_{25} alkanes/cycloalkanes fraction discussed by Shephard and McCarty (1997) and Shephard and Webb (1998).

Since the known releases of untreated wastewater and treatment fluids were all more than a decade ago (Exponent 2000), the bulk of the hydrocarbon residues reported as "PHC as Diesel" in AOC B are likely to be strongly sorbed to sediments. The principal routes of exposure to ecological receptors would be to infaunal benthic invertebrates via direct contact with sediment pore water and ingestion of sediment/detrital particles. The tendency for bioconcentration and bioaccumulation would vary among the constituent compounds and receptor groups, but generally would not be expected (particularly at this late stage in the weathering cycle) to be significant. Biomagnification of petroleum hydrocarbons in general through trophic levels has not been observed (Irwin *et al.* 1997).

2.1.3.3 Polycyclic Aromatic Hydrocarbons (PAHs)

PAH compounds are composed of carbon and hydrogen in the form of two or more benzene rings in linear, angular, or cluster arrangements which may have various substituted groups attached to one or more rings (Neff 1985; Eisler 1987). There are thousands of such compounds, but those of ecotoxicological concern are the "mobile" forms with molecular weights ranging from about 128 to 300. There are about 16 to 18 better-known compounds that are typically included, among semi-volatile organic compounds (SVOCs), in reports from analyses performed under SW-846 Methods 8270 or 8310. Within this broad group, a distinction is made in this SLERA between low molecular weight PAHs (LPAHs; i.e., <200) and high molecular weight PAHs (HPAHs; i.e., >200). The former are unsubstituted compounds with 2 to 3 rings (e.g., naphthalene, fluorene, phenanthrene), while the latter contain 4 to 7 rings and are commonly substituted (e.g., benzo(a)pyrene, benzo(b)fluoranthene, chrysene).

The main reason for the distinction is that PAHs of different molecular weights vary substantially in their environmental behavior (especially aqueous solubility) and toxicity (USEPA 1980; Neff 1985; Hellou 1996). For example, the LPAHs generally have aqueous solubilities in the high μg/L to mg/L range, and octanol-water partitioning coefficients (K_{ow}s) well below 5, whereas the HPAHs have solubilities in the sub-μg/L to low μg/L range and K_{ow}s generally above 5. Elevated bulk-sediment PAH concentrations, primarily HPAHs, were reported in four of the six CHB samples.

PAHs in general can undergo photolysis, oxidation, and biodegradation (USEPA 1980; Eisler 1987; Lyman 1995), with rates tending to decrease with increasing molecular weight and complexity. Photooxidation may be the most significant transformation process affecting bioavailability of PAHs (Holst and Giesy 1989; Duxbury *et al.* 1997; Huang *et al.* 1997). Therefore, light penetration, particularly in the littoral zone, may be a significant factor in CHB. The most significant biodegradation occurs aerobically with acclimated microbial populations (Lyman 1995); the highly ringed HPAHs are generally more resistant to biodegradation than the LPAHs.

Despite their relatively high K_{ow}s and lipophilicity, PAHs show little tendency to biomagnify in food chains (Neff 1985; Eisler 1987; Spacie *et al.* 1995). They are readily absorbed, either

directly (to the extent dissolved in water) or via ingestion, but then tend to be rapidly metabolized by most organisms. Notable exceptions are bivalve mollusks, which tend to accumulate relatively high levels of PAHs via ingestion of suspended and detrital particles and are unable to metabolize and excrete them -- due to inefficient or missing mixed-function oxidase (MFO) enzyme systems (Sirota and Uthe 1981; Lawrence and Weber 1984; Hellou 1996).

Based on the foregoing, it is expected that the most significant PAH exposures to aquatic organisms in CHB involve individuals that are, or tend to be, in intimate physical contact with the sediments where the highest concentrations exist. Since bivalve mollusks (e.g., clams) are unlikely to be a major component of the benthic invertebrate community, if even present at all[3], exposures of PAHs to aquatically dependent tetrapod vertebrates ("wildlife") are unlikely to be significant.

2.1.3.4 Chlorinated Phenols

The only chlorinated phenol or metabolite detected in CHB and drainage ditch sediments was pentachlorophenol (PCP). This compound is a major wood-preservative used at the facility throughout its history, and several inadvertent releases to CHB are mentioned in Exponent (2000). Photolysis rapidly breaks down PCP in surface water and, after a period of microbial acclimation (up to several weeks), biodegradation usually becomes a significant fate process (USEPA 1979). However, PCP also has a strong affinity for sorption to soils and sediments, particularly at lower pHs and with increased organic content. PCP has a relatively low aqueous solubility (14 mg/L at $20°$ C; Verscheuren 1982) and volatility.

Ecological receptors generally absorb PCP rapidly, but will also rapidly excrete it. Therefore, even though the K_{ow} is relatively high (slightly >5), the potential for bioconcentration and bioaccumulation is only moderate and biomagnification has not been observed (USEPA 1999a).

---

[3] Although substantial evidence was observed, during the ecological reconnaissance of wading birds and raccoons feeding in littoral areas, no "relic" shells of bivalves were noted. Typically, where clams and/or mussels are abundant, they are heavily used by such wildlife and localized concentrations of discarded shells are conspicuous.

2.1.4 Ecotoxicity and Potential Receptors

2.1.4.1 Modes of Toxic Action

In classical toxicology, the terms mechanism of toxicity or mode of toxic action relate to specific target tissues/organs or processes within a receptor that are pathologically affected by the presence of a 'poison.' In ecological risk assessment (and especially SLERA) the terms are typically equated with general outcomes, such as "impaired reproduction," rather than the exact biochemical or physiological mechanism by which reproduction is impaired. The understanding of how a COI might affect organisms, and the relative sensitivities of various organisms, can narrow the focus of the overall risk assessment by contributing to the development of assessment endpoints (Subsection 2.1.6).

Since any substance can, at some level of exposure, be "toxic," all of the COIs considered in this SLERA could be expected (theoretically) to elicit sublethal or chronic effects on individual organisms at exposure levels well below those that would overtly kill the organisms. Except in situations where legally protected species may be exposed (which is not the case in AOC B; see Subsection 2.1.1), ecological risk assessment is concerned with effects on higher levels of biological organization, such as populations, communities, or ecosystems (Suter 1993; USEPA 1997, 1998). Therefore, the focus is on effects which: (1) occur at the lowest exposure levels; and (2) are relevant to population dynamics. For example, growth may be reduced at relatively higher exposure levels than those associated with impaired reproduction and the latter is deemed more significant from an ecological perspective. Responses considered relevant to population dynamics include mortality (reduced survival), impaired reproduction, developmental effects, and reduced growth, in that order of diminishing relative significance.

Carcinogenicity, although a major concern in human health risk assessment, is generally not considered a relevant endpoint for ecological risk assessment. This is because it is difficult to relate the significance of tumors (many of which would not necessarily have adverse physiological effects) in individual animals to population dynamics or higher levels of organization. When legally protected (e.g., ETC) species may be exposed, carcinogenicity could become relevant.

What follows is a short summary of what is known regarding the modes of toxicity of the COIs and their most significant chronic effects, insofar as discernible. An attempt is made to consider the most significant chronic effects in the context of the toxicological mechanism whenever possible. That is, if the mechanism is an estrogenic effect, the most significant response is expected to be related to reproduction (e.g., fertility, fetotoxicity), or if the mechanism is an interference with adenosine triphosphate (ATP) the expected response would be related to growth and/or development. This can only be done for those chemicals for which the level of understanding of the toxic mode and target tissues/organs is high. For some COIs, there is only rudimentary knowledge or conflicting theories. In virtually all cases where there is a high level of understanding, the toxicants are best understood/characterized in mammalian models, and the relationship to other ecological receptors is poorly (if at all) defined.

The information is compiled from toxicological excerpts from the online Hazardous Substance Database (HSDB); Assessment Tools for Evaluation of Risk Database (ASTER); available ATSDR Toxicological Profiles; U.S. Fish and Wildlife Service Contaminant Hazard Reviews (i.e., the "Eisler documents"); USEPA (1999a); and several basic texts on environmental toxicology (e.g., Dallinger and Rainbow 1993; Cockerham and Shane 1994; Rand 1995).

2.1.4.1.1   Arsenic

Arsenic is a cytotoxin whose mechanism of action involves the replacement of phosphate by arsenate, the usual form of arsenic found in biological tissues, and in ATP synthesis resulting in the inhibition of most cellular functions and enzyme systems (USEPA 1985; Eisler 1988a). There are teratogenic effects due to arsenic, which include fetotoxicity as well as embryonic malformations. Arsenic, however, is also necessary at certain levels to the physiology of most organisms (i.e., is an essential "micronutrient").

Growth in sensitive freshwater algae may be adversely affected by aqueous concentrations of As^{+5} <50 µg/L (Vocke *et al.* 1980), but generally algae are not affected by any form of arsenic at levels <75 µg/L (USEPA 1985). Vascular plants appear to be resistant to waterborne As at levels <2 mg/L (USEPA 1985; Eisler 1988a). The most sensitive chronic endpoints in plants relate to growth or survival.

Aquatic invertebrates and fish are generally resistant to water-column concentrations of all forms of arsenic in the high µg/L or even low mg/L ranges (USEPA 1985). However, some chronic effects have been reported for As^{+3} at concentrations in the low µg/L (<100) range (Spehar *et al.* 1980). Survival and development of narrow-mouthed toad eggs and tadpoles was reportedly affected by 40 µg/L sodium arsenite, although the effective concentration for development in a salamander was >4 mg/L (Birge 1978). Impairment of reproduction and growth in selected benthic invertebrates has been associated with bulk-sediment concentrations >13 mg/kg (Eisler 1988a).

Based on information summarized in Eisler (1988a) and Sample *et al.* (1996), it appears that dietary exposures of As^{+3} compounds greater than about 30 mg/kg and 5 mg/kg, respectively, will affect reproduction or survival in birds and mammals. Since arsenic does not particularly bioaccumulate (Linday and Sanders 1990), it appears that aquatic media associated with CHB would not pose a significant threat via ingestion to birds and mammals.

2.1.4.1.2   Chromium

Chromium is an essential micronutrient for glucose, lipid, and protein metabolism in animals (but not plants). Toxicity due to chromium exposure is related to its oxidative state and membrane permeability; the hexavalent form (Cr^{+6}) is the most toxic. Acute toxicity is characterized by oxidation of tissue. Chronic toxicity may be related to non-specific protein/enzyme binding or perhaps oxidative stress within cells (Eisler 1986; Irwin *et al.* 1997).

In plants, chromium appears to interfere with the transport and metabolism of essential minerals, especially cadmium, potassium, manganese, boron, and copper (Efroymson *et al.* 1997). Reduced growth in vascular plants has been reported at bulk-medium concentrations of Cr^{+6} in the range of 2 to 10 mg/kg; however, the threshold for the more common Cr^{+3} is substantially higher.

In aquatic animals, chromium's non-specific binding and potential cellular oxidative stress results in non-specific toxicology. Based on review of available data rather than a specific toxicology, reproduction appears to be the most significant chronic endpoint. Effects of "total chromium" on sensitive benthic invertebrates are generally manifested at sediment concentrations >40 mg/kg.

In terrestrial and semi-aquatic (air-breathing) vertebrates, chromium appears to be mainly a contact poison by actively attacking respiratory tissues (Eisler 1986). Oral exposure appears to be relatively innocuous, especially in mammals. Even in birds, which appear to be much more sensitive, effects are only elicited at dietary concentrations in the range of 50 mg/kg (Sample *et al.* 1996). Reproductive, growth, and/or developmental endpoints are poorly established; therefore the most significant chronic endpoint is considered to be survival.

2.1.4.1.3 Copper

Copper is an essential micronutrient for protein formulation, including hemoglobin formation, carbohydrate metabolism, and catecholamine biosynthesis in animals. The mechanism(s) for toxicity due to over-exposure to copper is unclear, but it is believed to be related to cellular oxidative stress via cellular membrane hypoxia and/or an accumulation in hepatocytes leading to degeneration of mitochondria and necrosis.

Copper is significantly phytotoxic, and is a common active ingredient in algicides. It is postulated that copper causes a toxic imbalance by interfering with other metal-mediated enzymatic reactions within plant cells (Efroymson *et al.* 1997a). The most significant chronic endpoints are related to survival (algae) and survival and growth (vascular plants). In terrestrial and hydrophytic vascular plants, copper plays a significant role in photosynthesis, respiration, carbohydrate distribution, nitrogen reduction and fixation, protein metabolism, and cell wall metabolism. The level of copper in soils and sediments reported by several authors to be phytotoxic is in the high tens of mg/kg (e.g., generally around 100).

Aquatic animals in general are very sensitive to copper; the toxicity is believed to be dominated by the relationship between gill tissue damage (contact irritation) and hematological effects on osmoregulation. Specific sublethal, chronic, endpoints have not been fully established for most groups of aquatic animals. Review of the data suggests that survival is the most significant chronic endpoint. The toxicity of copper in the water column is hardness dependent. Effects of copper on sensitive benthic invertebrates are generally manifested at sediment concentrations >30 mg/kg.

In terrestrial and semi-aquatic vertebrates, copper is: (1) a contact irritant within the gastro-intestinal tract; and (2) a potential inducer of cellular oxidative stress. No specific

developmental or reproductive effects have been conclusively identified; thus, the most significant chronic endpoint is considered to be survival. Mammals appear to be slightly more sensitive to dietary exposures than birds; survival tends to be reduced at dietary concentrations of about 100 mg/kg for mammals and >500 mg/kg for birds (Sample *et al.* 1996).

2.1.4.1.4   Lead

Lead in its inorganic form is known for its inhibition of hemoglobin synthesis and resultant anemia, which has been correlated with lead-associated alpha-aminolevulinic acid dehydrogenase (ALAD) inhibition. Neurotoxicity and kidney dysfunction due to lead poisoning are also well documented, but are generally associated with overt/acute exposures (ingestion of lead pellets by birds) (Eisler 1988b; Irwin *et al.* 1997).

Plants in general are resistant to lead; the most significant chronic endpoint is growth. Lead in vascular plants has no known physiological function (although lead appears to be a natural constituent in the tissues). Phytotoxic effects of lead are elicited in soils and sediments at bulk-medium concentrations from about 50 to 5,000 mg/kg. It appears that the sediment pH and form of lead added have a significant influence on the toxicity observed.

In aquatic animals, acute lead exposure affects invertebrates much more readily than fish. This is believed to be associated with the differences in liver enzyme function (i.e., metal-binding proteins). Crustaceans are at most risk due to interference with metal mobilization processes during molting events. The aqueous toxicity is hardness-dependent. Effects of lead on sensitive benthic invertebrates are generally manifested at sediment concentrations >35 mg/kg.

Among terrestrial and semi-aquatic vertebrates, birds tend to be relatively sensitive to lead poisoning, while mammals appear to be slightly less sensitive (ignoring ingestion of lead pellets by waterfowl). Neurological, behavioral, and metabolic effects (often manifested as reduced growth) appear to be the most significant chronic effects in birds. The most significant chronic effects in mammals appear to be related to fertility (reproduction) and development. Effects tend to be elicited at dietary concentrations > about 50 mg/kg and > about 500 mg/kg in birds and mammals, respectively (Eisler 1988b).

2.1.4.1.5　Nickel

Although nickel (in certain forms) can elicit adverse effects on growth of plants, as well as reproductive and developmental effects in animals, the mechanisms of toxicity are poorly understood (Efroymson *et al.* 1997a; Eisler 1998b). As noted in Subsection 2.1.3.1.5, nickel was detected only once in CHB sediments. Moreover, the level reported was at least an order of magnitude lower than that believed to pose a hazard to sensitive benthic invertebrates (McDonald *et al.* 1999), and several orders of magnitude below levels reported to be toxic to vascular plants (Efroymson *et al.* 1997a) or wildlife receptors (Sample *et al.* 1996).

2.1.4.1.6　"PHC as Diesel"

Alkanes elicit their toxic effects via narcosis (i.e., anaethesia), a non-specific, reversible, disruption of neural activity. This in turn can lead to indirect adverse results such as reduced respiratory rates, behavioral changes that can retard feeding (hence affect growth) and ability to escape predation, and other physiological changes. Two theories about the precise mechanism(s) of narcosis are discussed in the following subsection on PAHs.

It has been demonstrated that, in most aquatic organisms, the lethal body burden of narcotics is constant within a narrow range of tissue concentrations (2-8 millimoles/kg), with chronic toxicity thresholds at about 10% of the lethal body burden (Shephard and Webb 1998). The toxicity of narcotic mixtures is additive, so the composition of the mixture does not drive the response. Instead, toxicity is observed when the sum of the molar concentrations of individual mixture components exceeds a critical body residue, set at 0.24 mmol/kg for alkanes (Shephard and McCarty 1997; Shephard and Webb 1998).

The foregoing relationship has been used in conjunction with the equilibrium partitioning (EqP) procedure to develop a sediment ESV expressed in terms of organic carbon (see Subsection 2.2). Toxicity of the "PHC as Diesel" residues via direct contact to aquatic or hydrophytic vascular plants, or via ingestion to wildlife would depend on the relative proportions of constituent compounds and is therefore difficult to predict with the information available (Irwin *et al.* 1997). Oiling of vegetation, if of sufficient magnitude and duration, may have had some minimal effects soon after the releases, but the effects of the current weathered mixture are unlikely to be significant. Although substantial literature is available on the effects of ingestion of various crude oils (primarily in fresh state) by birds

and mammals, comparable information does not appear to be available for diesel mixtures (Irwin *et al.* 1997). As a point of reference, a dietary concentration of 20,000 mg/kg of naturally weathered crude oil did not adversely affect reproduction in mallard ducks (Stubblefield *et al.* 1995).

2.1.4.1.7 Polycyclic Aromatic Hydrocarbons

Laboratory bioassays have demonstrated a wide variety of adverse biological effects in numerous kinds of organisms due to exposures to individual PAHs (USEPA 1980; Eisler 1987; Hellou 1996). Such effects include reduced survival, reproduction, growth, metabolism, disease resistance, and (especially) increased tumorigenesis. However, the inter- and intraspecies responses to PAHs are highly variable, and are substantially modified by numerous factors, including the presence of other chemicals (particularly other PAHs). Until these interaction effects are better understood, application of the single-substance bioassay results in interpretation of field situations will be of very limited value (Eisler 1987; Hellou 1996).

Much of the research on PAHs has focused on carcinogenicity in mammals, which has been demonstrated (or at least roughly implicated) for certain HPAHs. The noncarcinogenic toxicity of PAHs is believed to act through basic metabolic disruption and is usually reflected as polar narcosis. There are presently two theories regarding how narcosis occurs within an organism (Abernethy and Mackay 1988). The "critical volume" theory involves a swelling or volume change due to dissolved toxicant in nerve cells that results in changes in the structure of lipid bilayers within the cell membrane. The "protein binding" theory involves the toxicant binding to specific receptor sites of certain dimensions within the nerve cells, resulting in narcosis. Whichever theory is applied, the molecular weight (size) of the PAH will determine the effective concentration and/or dose [see discussion of petroleum hydrocarbons above]. The available toxicological data bear this out (Abernethy and Mackay 1988). Therefore, as in the case of environmental fate, the recognition of LPAHs *versus* HPAHs is important.

2.1.4.1.7.1 *Low Molecular Weight PAHs*

LPAHs may serve as a carbon source to higher plants and, as such, there are suggestions that they enhance primary productivity. In any case, both algae and vascular plants tend to be

resistant. Over-exposure to LPAHs can inhibit growth; however, the effects are generally elicited at aqueous concentrations >20 µg/L.

In aquatic animals the most significant chronic endpoints are survival and growth; effects of water-column exposures (e.g., to zooplankton [microcrustaceans] and fish) are generally manifested in the mid- to high µg/L, or low mg/L, range.

In terrestrial vertebrates the most significant chronic endpoints are survival and growth. Birds appear to be relatively tolerant to dietary exposures, as evidenced by no effects on survival in mallards fed naphthalene and phenanthrene at concentrations up to 4,000 mg/kg Patton and Dieter 1980).

2.1.4.1.7.2 *High Molecular Weight PAHs*

Algae appear to be slightly more sensitive to HPAHs and LPAHs, perhaps due to direct cell wall effects on permeability. Nevertheless, the aqueous concentration of benzo(a)pyrene known to elicit effects on algal growth is 25 µg/L (Cody *et al.* 1984). Vascular plants are resistant; i.e., growth inhibition appears to be manifested only when bulk-media concentrations are in the high µg/kg to low mg/kg range (Huang *et al.* 1997).

Aquatic animals tend to be sensitive to HPAHs (insofar as they are bioavailable). The most significant chronic responses tend to relate to survival and growth. Chronic effects on zooplankton (cladocerans) and fish have been reported at aqueous concentrations in the low- to mid µg/L range (Trucco *et al.* 1983; Eisler 1987).

In terrestrial vertebrates (at least birds and mammals), the HPAHs appear capable of eliciting reproductive and developmental effects. Sample *et al.* (1996) estimate that dietary concentrations as low as 19 mg/kg benzo(a)pyrene might impair reproduction in sensitive mammals, based on experiments with mice (Mackenzie and Angevine 1981).

2.1.4.1.8 Pentachlorophenol

Acute exposures of PCP to animals result in interference with the production of high energy phosphate compounds needed for cellular respiration (uncoupling oxidative phosphorylation).

At chronic exposures there also appear to be general inhibitory effects on a variety of enzymes, metabolism of lipids and carbohydrates, ion transport, and protein synthesis (Rao 1978; Eisler 1989). Among general outcomes, these effects are manifested in fetotoxicity (impaired reproduction) and developmental (embryonic) malformations; however, evidence of mutagenic or carcinogenic properties is incomplete (Williams 1982). The mechanism of toxicity in plants is not fully understood (Efroymson *et al.* 1997a); however, it is believed that oxidative phosphorylation, or a similar process, is the mechanism of PCP phytotoxicity (Eisler 1989).

Effects of PCP on growth in terrestrial and hydrophytic vascular plants vary substantially with clay content within the medium, but are generally elicited at concentrations >3 mg/kg (Efroymson *et al.* 1997a).

Aquatic toxicity of PCP is highly dependent upon pH. Effects on growth, survival, and reproduction are elicited in the more sensitive organisms at aqueous concentrations in the low µg/L range (e.g., <10), especially when acidic conditions exist.

"Adverse sublethal effects" on birds are reported by Eisler (1989) to be associated with dietary concentrations as low as 1 mg/kg; however, the nature of the effects and the source of the information are not provided. Reproduction in laboratory rats was impaired at dietary concentrations of 30 mg/kg, but not at 3 mg/kg (Schwetz *et al.* 1978).

2.1.4.2 Potential Receptors

Based on the foregoing information regarding behavior and toxicology of the COIs (Subsections 2.1.3 and 2.1.4) the various potential ecological receptors can be prioritized relative to their vulnerability to exposures and sensitivities. For example, with the possible exceptions of arsenic, nickel, and PCP it is highly unlikely that aqueous (water-column) concentrations of the COIs would pose a threat to planktonic or nektonic (free-swimming) organisms in CHB. Also (again with the possible exception of PCP), it appears unlikely that any of the COIs would adversely affect aquatic and hydrophytic vascular plants -- since most (if not all) of the reported concentrations in sediments are well below thresholds for phytotoxicity. Inasmuch as the vast majority of the *mass* of all of the COIs is likely to be sequestered in the CHB sediments, it is concluded that the most vulnerable and sensitive receptors would be those intimately associated with the inundated substrates, particularly

those that essentially reside within the sediments. In CHB, such receptors would be infaunal benthic invertebrates, such as oligochaetes (segmented worms), a few types of microcrustaceans (especially amphipods), and a variety of insects whose larval stages burrow in the sediment (e.g., certain mayflies and midges).

Because of the probable limitations on bioavailability and limited or no propensity for bioconcentration/bioaccumulation of most of the COIs, it appears that indirect exposures via ingestion to semi-aquatic and terrestrial vertebrates ("wildlife") is insignificant. However, some of the COIs (notably HPAHs and PCP) can elicit adverse responses in certain sensitive wildlife receptors at relatively low dietary concentrations. Certain semi-aquatic vertebrates may consume sufficient quantities of aquatic organisms and/or (incidentally) the sediment itself to be at risk. This would be particularly true of *individual animals* that might feed preferentially or exclusively along CHB (e.g., territorial "piscivorous" birds and mammals).

2.1.5 Complete Exposure Pathways

Figure 2 addresses the complete and potentially significant exposure pathways to ecological receptors in AOC B. The primary or ultimate sources of COIs are surface soils of treatment areas of the main International Paper facility. The initial release mechanism is conceived as advective transport via surface runoff, primarily coalesced in the several drainage ditches (i.e., part of SWMU 37), followed by deposition onto wetland and aquatic soils/sediments. From these secondary sources, the COIs may be released by desorption to surface water and/or interstitial ("pore") water, to which primary receptors may be directly exposed.

Tertiary release mechanisms would include uptake via direct contact and/or ingestion by organisms living in the sediments or the water column, followed by the ingestion of these organisms by semi-aquatic (air-breathing) animals.

2.1.6 Ecological Endpoints

Among the crucial products of problem formulation are assessment endpoints, which provide a bridge between broad management or policy goals (e.g., "protection of the environment") and the specific measurements used in risk evaluation. *An assessment endpoint is the explicit expression of an environmental value that is to be protected* (USEPA 1997, 1998). Two elements are needed to define an assessment endpoint: (1) the valued ecological entity (e.g., a

URS

local population of a species, or a particular habitat such as emergent aquatic vegetation); and (2) the property or attribute of that entity which is potentially at risk and important to protect. The rationale for endpoint selection must be clear. Much of the information presented in the foregoing subsections is intended to provide rational (and transparent) bases for endpoint selection.

As noted above, at a fundamental level, it is individual organisms that are exposed (directly or indirectly), and individuals that respond. However, one of the salient differences between human health and ecological risk assessment is that the latter "involves multiple endpoints at different levels of biological organization, from single species to communities of organisms to entire ecosystems" (USEPA 1991; see also Suter 1993). Generally, it is the potential effects on populations or even higher levels of biological organization that are of interest in ecological risk assessment (Suter 1993; USEPA 1998).

The ecological entities and properties deemed appropriate for this SLERA should be those necessary to "sustain the natural structure and function of an ecosystem" (USEPA 1998). The "ecosystem" at issue here is the assemblage of organisms and their habitats associated with CHB to the northeast of (and downgradient from) the main International Ppaper - Wiggins facility. The ecological "integrity" (structure and function) of this system might be altered by the presence of one or more of the COIs. As with any natural ecosystem, the structure and function of the CHB system will be regulated by ecological entities that fall into three fundamental trophic groups:

- **Producers** (autotrophs), or organisms that use sunlight to manufacture organic matter (biomass) from inorganic chemicals -- i.e., **green plants**

- **Consumers**, or organisms that feed on other organisms -- i.e., **animals**, which in turn are classified as:

    - Primary consumers (plant-eaters or herbivores)
    - Secondary consumers (omnivores)
    - Tertiary/quaternary consumers (carnivores)
    - Consumers of dead, often partially decomposed biological tissue, and biological waste (detritivores).

- **Decomposers**, or organisms that convert dead biological tissue (detritus) and biological waste materials into simpler organic molecules -- i.e., **bacteria and fungi** ("microbes").

The producers and decomposers are, for the most part, intimately associated with fixed substrates (e.g., sediments), and tend to be morphologically and physiologically similar. Most consumers (animals) are more mobile, and comparatively more complex organisms, than plants and microbes. Thus there is greater diversity, in the sense of higher taxonomic levels, of animals than simpler organisms that function as producers and decomposers. It is generally the animals (consumers) -- especially the larger, more conspicuous forms -- that tend to be accorded higher "value" by human society (i.e., as "wildlife"). However, if the system is to be "natural," then entities from all three trophic levels must be protected.

Based on the information summarized in Subsection 2.1.4, it is concluded that the more vulnerable and potentially sensitive receptors in CHB would be certain groups of aquatic invertebrates whose survival, growth, and/or reproduction might be impaired by direct exposures to sediments (primarily via the pore waters). Such receptors, at the screening level, are represented by the assemblage of populations commonly referred to as the *infaunal benthic community*. The attribute of this community that is of concern – i.e., of essential relevance to the integrity of the overall system – is conceived as "secondary production" (provision of biomass in a form available for higher-level consumers. In terms of actual measurement(s), which is beyond the scope of this investigation, the property could be reflected in community composition (e.g., the taxonomic diversity) and structure (e.g., relative densities).

At least with respect to most of the COIs, it appears unlikely that the vulnerability and sensitivity of higher-level consumers via direct or indirect exposures would be significant. Certain wildlife could conceivably, however, ingest sufficient quantities of lower-level aquatic consumers and/or sediments to be susceptible to adverse chronic effects from some of the COIs (e.g., HPAHs and PCP). Accordingly, a second broad assessment endpoint is potential impaired reproduction and/or developmental effects in sensitive birds and mammals. Such receptors might include individual wood ducks (*Aix sponsa*; an omnivore); belted kingfishers (*Ceryle alcyon*; a carnivore); beavers (*Castor canadensis*; an herbivore); raccoons (*Procyon lotor*; an omnivore); and mink (*Mustela vison*; a carnivore). Neither kingfishers nor mink were actually observed (directly or indirectly) in AOC B during the

ecological reconnaissance, but individuals could occasionally be present. Wood ducks, beaver, and raccoon appear to be common along CHB. All of these air-breathing species are "semi-aquatic" in the sense that they tend to be intimately associated with aquatic and wetland habitats, from which they typically obtain a large proportion of their diet.

It should be acknowledged that certain amphibians and reptiles (e.g., bullfrogs and some other "true" frogs, some salamanders, turtles, water snakes) may be among the most vulnerable wildlife to exposures in AOC B. Compared to most birds and mammals, amphibians and reptiles (especially the former) are relatively sedentary. Eggs and larvae (tadpoles) of bullfrogs (*Rana catesbeiana*) are strictly aquatic, and therefore would be directly exposed to any bioavailable (i.e., dissolved) fractions of COIs in the water column. The tadpoles feed almost exclusively on benthic algae, periphyton, and vegetable detritus (USEPA 1993a). Although basically air-breathers, adult bullfrogs also respire "aquatically" through the skin and other integumentary tissues (e.g., cloacal wall). These animals hibernate during cold months by burying themselves in surficial aquatic or riparian sediments, with maintenance respiration dependent upon dissolved oxygen from the pore water. Adult bullfrogs are carnivorous, preying on a wide variety of aquatic and semi-aquatic animals (basically anything alive that is small enough to swallow). However, other than results of direct-exposure bioassays (tadpoles in water), there are virtually no reliable toxicological data available by means of which to evaluate the potential effects of exposures to amphibians and reptiles. It should be noted that amphibians (including bullfrogs) and semi-aquatic reptiles were observed to be common along and in CHB during the ecological reconnaissance, which indicates at a minimum that these animals as a group are not experiencing any overtly adverse effects.

2.2   ECOLOGICAL EFFECTS EVALUATION

Evaluation of ecological effects at the screening level requires: (1) bulk-medium concentrations of the COIs representative of conservative thresholds at or above which adverse toxicological responses would be expected (i.e., ESVs); and (2) exposure estimates. The latter are discussed in Section Three.

This SLERA was initiated to address the basic premise that COIs related to the International Paper - Wiggins facility may pose hazards to ecological resources. Such constituents would be identified as chemicals of potential ecological concern (COPECs), and may be subject to

further evaluation via a more definitive ecological risk assessment. As in the case of defining ecological endpoints (Subsection 2.1.6), there is a need to limit the scope to an immediately relevant, tractable, group of COPECs -- i.e., those which:

- Are truly related (at least indirectly) to the International Paper facility; and

- Might, at least conceivably, elicit substantive adverse effects (i.e., changes that irreversibly compromise the structural and functional integrity of the ecosystem(s) and/or the health of legally protected individual organisms.

This subsection addresses the overall approach to identifying COPECs, with particular emphasis on establishing a rationale for their selection. Results of the sampling and analysis of CHB sediments are used to identify COPECs, eliminate some COIs, and recognize COIs whose status is unresolved (i.e., uncertainties).

Screening of COIs should be a process that leads to some degree of prioritization. It should narrow the list to COPECs whose effects are known or at least practicably discernible [see above discussion regarding availability of toxicity data for amphibians and reptiles]. This means that some COIs will be eliminated by the process, or at least relegated to the status of uncertainties that can only be addressed qualitatively/intuitively. If the screen is so fine as to retain all (or virtually all) of the COIs, it has no operational value in problem formulation.

Frequency of detection, although relevant later, is not a primary consideration in the initial selection of COPECs. In cases where practical analytical sensitivities (i.e., analytical reporting limits) are inadequate to verify absence of COIs at levels exceeding ESVs, the consituents are considered uncertainties rather than COPECs. The inability to obtain measurements of these substances necessitates a different, fundamentally qualitative approach to subsequent evaluation.

2.2.1 Direct-Exposure Screening Values

Direct-exposure (to benthic invertebrates) ESVs for freshwater sediments were obtained from five sources as identified in Table 1. All of the ESVs for inorganic COIs and most of those for organics are experimentally derived, effects-based values believed to represent thresholds below which adverse responses are highly improbable (i.e., consensus-based threshold effects

concentrations [TECs; MacDonald *et al.* 1999]; threshold effects levels [TELs; Ingersoll *et al.* 1996]; or effects range - low values [ERLs; Long *et al.* 1995]. Preference was given to TECs, TELs, and ERLs because they are the most conservative benchmarks available for freshwater sediments that have a solid technical basis[4].

There are no available sediment ESVs that are based on directly observed effects for "PHC as Diesel" or PCP. This necessitated deriving benchmarks using the equilibrium partitioning approach (USEPA 1993b), with the lowest available aqueous toxicity ESV (e.g., the freshwater chronic value) and expected partitioning from sediment to pore water. The basic EqP equation is:

$$SC = C_w * f_{oc} * K_{oc}$$

where,

SC = EqP based screening concentration in sediment
K_{oc} = organic carbon to water partitioning coefficient
f_{oc} = screening value in water (0.01 assuming an organic carbon concentration of 1%)
C_w = screening value in water

In the case of "PHC as Diesel" the process was extended to account for the actual measured total organic carbon (TOC) associated with a particular sediment sample, and transforming the ESV and estimated exposure concentrations to express them in terms of organic carbon (mg/kg-oc; Shephard and Webb 1998).

2.2.2   Indirect (Ingestion-Pathway) Screening Values

Addressing potential indirect exposures to wildlife via ingestion is accomplished by identifying what are believed to be the most conservative no-observed-adverse-effects-levels (NOAELs) for ingestion of food, water, and (incidentally) sediments by tetrapod vertebrates (i.e., birds and mammals) for each COI. The NOAEL is an exposure *rate* or dose, expressed as milligrams per kilogram of receptor body weight per day (mg/kg-BW/day). Using the

---

[4] In general, they are also the most recently published values (at least in peer-reviewed scientific literature).

rates of water, food, and sediment ingestion for the test organism[5] used in deriving the NOAEL, the corresponding dietary concentrations were back-calculated to serve as sediment ESVs by:

$$SC \ (mg/kg) = NOAEL \ (mgCOI/kg\text{-}BW/day) * BW \ (kg) * 1 \ day/(kg \ consumed)$$

where,

SC = screening concentration in sediment
NOAEL = no-observed-adverse-effects-level (dose)
COI = constituent of interest
BW = body weight (test organism, in kg)

The concentrations in food (forage/prey) and water are estimated using partitioning and "uptake" factors such as bioconcentration factors (BCFs), bioaccumulation factors (BAFs), biota-sediment accumulation factors (BSAFs), and/or food-chain multipliers (FCMs). The result is a conservative risk-based bulk-sediment concentration for the COI and a particular type of receptor. A sediment ESV was derived for each of the inorganic COIs, LPAHs, HPAHs, and PCP, relative to each of five types of receptors: mallard duck (a surrogate for wood duck); belted kingfisher; beaver; raccoon; and mink. Then the lowest ESV for each COI/receptor combination was selected as the ingestion-pathway ESV for Table 1.

The details of ingestion-pathway ESV derivation, including both selection (or derivation) of NOAEL doses and receptor-specific exposure assumptions are presented in Appendix A.

---

[5] In many cases the actual test animals were not the receptors chosen as "representative sensitive wildlife" species for AOC B (see Subsection 2.1.6).

3.1 EXPOSURE ESTIMATES

In accordance with USEPA (1997) the maximum reported bulk-sediment concentration (dry weight) from among the six CHB sampling locations is used as the estimated exposure concentration for screening. For "PHC as Diesel" this concentration is expressed as mg/kg - organic carbon (oc), to facilitate direct comparison with the ESV.

ESVs are available for certain of the PAH groups. Therefore, it was necessary to estimate a concentration for Total LPAHs, Total HPAHs, and Total PAHs. In these summations, the non-detected individual compounds were included in the respective summations only if a compound was quantitated at least once from indicator location samples. In such cases, one-half of the detection limit was used for each non-detected compound in a given sample.

3.2 RISK CHARACTERIZATION

3.2.1 Identification of Constituents of Potential Ecological Concern (COPECs)

3.2.1.1 Inorganics

Table 1 summarizes the results of comparing hypothetically potential exposures with ESVs. None of the inorganic COIs (As, Cr, Cu, Pb, Ni) is expected to elicit any adverse ecological effects, based on the lack of exceedances of any benchmarks. Thus none of the inorganics is elevated to the status of COPEC.

3.2.1.2 Petroleum Hydrocarbons

Similarly, the maximum reported concentration of "PHC as Diesel" does not exceed the only available effects-based ESV (9060 mg/kg-oc; Shephard and Webb 1998), which is for direct exposures to benthic invertebrates. As discussed in Subsection 2.2.2, there is not a reliable NOAEL-based ESV for ingestion-pathway exposures of petroleum alkanes/cycloalkanes (C_{10} - C_{25} fraction) mixtures to wildlife.

3.2.1.3 Polycyclic Aromatic Hydrocarbons

Maximum reported concentrations of seven individual PAH compounds (1 LPAH and 6 HPAHs), as well as Total LPAHs and Total HPAHs, exceeded their respective ESVs for direct exposure to benthic invertebrates. The exceedances for anthracene and Total LPAHs (and nearly all detections of other individual LPAHS) were associated with sampling locations 2 and 4 (Figure 1). Most of the exceedances for HPAHs were associated with the same two locations, although three of the individual compounds also exceeded their direct-exposure ESVs at location 3. Thus the exceedances for Total HPAHs were at locations 2, 3, and 4. Since the direct-exposure ESV for Total PAHs (1.61 mg/kg) is at least an order of magnitude higher than that for any individual compound or subgroup of compounds, it was approached only once, at location 4. The foregoing suggests that certain PAHs may pose a risk to sensitive benthic invertebrates, but that the potential is limited to the upper half of the segment of CHB within the AOC. The compounds or mixtures identified as COPECs for direct exposures are anthracene, Total LPAHs, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-c)pyrene, and Total HPAHs. Although never detected, acenaphthene is recognized as an uncertainty because its maximum analytical reporting limit (0.032 mg/kg) exceeds the applicable ESV (0.016 mg/kg).

Based on the conservative ESVs for Total LPAHs and Total HPAHs (as subgroups), there does not appear to be a potential for adverse effects on sensitive wildlife receptors via ingestion of aquatic organisms from CHB. The maximum concentration for Total LPAHs (0.260 mg/kg) is nearly three orders of magnitude lower than the benchmark (205 mg/kg), back calculated from a NOAEL dose (53 mg/kg-BW/day) for laboratory mice using conservative exposure assumptions representing a mink. The maximum concentration for Total HPAHs (1.02 mg/kg) is less than half of the benchmark (3 mg/kg), back calculated from a *derived* NOAEL dose (1 mg/kg-BW/day) for laboratory mice using the same mink exposure assumptions. The *measured* LOAEL dose (10 mg/kg-BW/day) used to derive the NOAEL elicited reproductive impairment in mice. The lowest NOAEL-based ESV for birds (a measured value), predicting reproductive impairment in the belted kingfisher, is 7.6 mg/kg Total HPAHs. Accordingly, none of the PAHs is identified as a COPEC for indirect (ingestion-pathway) exposures attributable to AOC B.

3.2.1.4 Chlorinated Phenols

Five of the six reported sediment concentrations of PCP exceeded both the direct- and indirect-exposure pathway ESVs. Furthermore, although PCP was not detected at location 1, the reporting limit for that analysis (0.095 mg/kg) was higher than both ESVs. These results reflect a potential for adverse effects on both aquatic biota and wildlife, so PCP is identified as a COPEC for both direct and ingestion-pathway exposures.

3.2.2 Evaluation of Uncertainty

The SLERA process is inherently conservative by design to minimize the likelihood of overlooking potential hazards to ecological receptors (USEPA 1997). Hence it is highly unlikely that any of the COIs not identified as COPECs (i.e., all inorganics, petroleum hydrocarbons, and most individual LPAHs) would pose a risk to benthic invertebrate animals, aquatic or hydrophytic vegetation, or wildlife foraging in and along CHB. Indeed, it is likely that potential hazards of most of the COPECs (particularly many of the individual and grouped PAHs) are over-estimated. Examples of factors contributing to over-estimation of risk include, but are not limited to:

- Although there were wide ranges of bulk-sediment concentrations of organic COIs, many of which did not exceed their respective ESVs, the selection process relied exclusively on the maximum reported levels.

- The ESVs for 25 of the 27 COIs were essentially based on "no-effects" levels, which may well be substantially below the actual thresholds for toxicological responses under conditions that actually exist in AOC B.

- The SVOCs retained as COPECs all tend to have a strong propensity for sorption to sediments, particularly where TOC levels are relatively high and reducing conditions prevail. This means that the vast bulk of the *mass* of these substances is effectively sequestered in the sediments and would have limited bioavailability; yet the bioassays on which many of the ESVs are based involved laboratory conditions designed to maximize availability of the COIs.

- Exposure assumptions for the ingestion pathway scenarios are generally unrealistic. For example, the foraging areas of individual mink and kingfishers are reportedly greater than 4,000 feet and 1,200 feet of shoreline, respectively (USEPA 1993a), whereas the stretch of CHB containing sediments with substantially elevated PCP (sampling locations 2-4) appears to be less than 1,000 feet. The ultraconservative risk-based sediment concentration derived for wildlife assumes that an individual mink derives every morsel of food it eats from the vicinity of CHB sampling location 4. Moreover, it assumes 100% assimilation of everything in the diet -- which is bioenergetically impossible.

Examples of factors that could conceivably have contributed to under-estimation of risk include:

- Lack of reliable dietary ESVs for amphibians and reptiles (particularly the former) precludes an adequate evaluation of receptors that are potentially more vulnerable to exposures than birds and mammals.

- Use of EqP-based ESVs (for "PHC as Diesel" and PCP) may not adequately account for toxicity attributable to ingestion-pathway exposures to certain types of infaunal benthic invertebrates, such as oligochaetes.

Examples of factors that could have contributed to either under- or over-estimation of the potential hazards include:

- Lack of site-specific limnological and water-quality data which, among other considerations:
  - constrains interpretation of the potential behavior and toxicity of COIs reported from sediments; and
  - limits direct evaluation of the potential aqueous toxicity (including availability for uptake and estimating exposures to higher trophic levels).

URS believes that, on balance, the SLERA is adequate to support a conclusion that further evaluation, focused on the constituents now considered COPECs is warranted. Certain data gaps need to be resolved, such as soils in the drainage ditches that convey runoff from the site to CHB, as well as a more extensive characterization in areas between the ditches. Surface

water in CHB needs to be evaluated to confirm an expectation that the COPECs are largely, if not completely, sequestered in the sediments. Such a refined assessment is likely to show that the potential for adverse ecological effects, if any, is relatively low. Moreover, any effects are likely to be of relatively low significance.

An ecological reconnaissance revealed that AOC B supports perennial (resident) aquatic biotic communities as well as semi-aquatic to terrestrial communities associated with the riparian zone of Church House Branch (CHB). The extreme upper reaches of the stream itself may only have intermittent, seasonal, flow, but beavers have established several impoundments that offer lentic refugia for aquatic plants and animals, as well as gradual expansion of palustrine wetland habitats.

As part of the RFI, six indicator and two background locations were sampled to evaluate the extent of occurrence of COIs in AOC B sediments. Analyses of the eight composite samples indicated that CHB sediments contain elevated levels of certain metals (Cr, Cu, Pb)[6], a metalloid (As), a petroleum hydrocarbon mixture, certain PAHs, and PCP. The maximum reported concentrations of these COIs were compared to conservative benchmarks (ESVs) to determine if any has a potential to cause adverse ecological effects. Chemicals that exceeded their respective ESVs were designated constituents of potential ecological concern (COPECs). The COPECs, as well as any COIs of uncertain status, may require further evaluation in a refined ecological risk assessment.

Eight individual semi-volatile organic compounds and two groups were identified as COPECs as follows:

> Anthracene
> Total LPAHs
> Benzo(a)pyrene
> Benzo(b)fluoranthene
> Benzo(g,h,i)perylene
> Benzo(k)fluoranthene
> Chrysene
> Indeno(1,2,3-c)pyrene
> Total HPAHs
> Pentachlorophenol (PCP)

Because of the conservatism inherent in the SLERA process it is highly unlikely that any of the COIs not identified as COPECs (i.e., all inorganics, petroleum hydrocarbons, and several

---

[6] Nickel was reported at 2 mg/kg in one indicator sample, but this concentration is an order of magnitude lower than levels generally regarded as unnaturally elevated.

semi-volatile organics) would pose a hazard to benthic invertebrate animals, aquatic or hydrophytic vegetation, or wildlife foraging in and along CHB. Similarly, although they might, theoretically, pose a limited threat to benthic invertebrates, it is highly unlikely that PAHs (individually or collectively) would elicit adverse effects among wildlife receptors.

Since the semi-volatile organic constituents retained as COPECs tend to have a propensity for sorption to sediments, particularly where (as in CHB) TOC levels are relatively high, it is reasonable to suppose that the vast bulk of the *mass* of these substances is effectively sequestered in the sediments of AOC B. The same is generally true of the inorganics, although their behavior is more complex and heavily dependent upon speciation, valence state, and various other physico-chemical factors (e.g., pH, hardness). Therefore, it may be that insufficient quantities of these substances are available to achieve concentrations in the overlying surface water to pose a hazard to organisms in the water column (e.g., plankton, fish, larval amphibians).

The uncertainty associated with this SLERA that could substantially alter the basic conclusions is related to lack of information on: (1) "conventional" water-quality conditions (e.g., pH, Eh, dissolved oxygen); (2) aqueous concentrations of the COIs (both dissolved and total); and (3) details of the spatial distribution of COIs within the sediments.

Abernethy, S.G., and D. Mackay. 1988. "Volume fraction" correlation for narcosis in aquatic organisms: the key role of partitioning. *Environmental Toxicology and Chemistry* 7:469-481.

Aggett, J., and L.S. Roberts. 1986. Insight into the mechanism of accumulation or arsenate and phosphate in hydro lake sediments by measuring the rate of dissolution with ethylenediamenetetracetic acid. *Environmental Science and Technology* 20:183-186.

Ankley, G.T., D.M. DiToro, D.J. Hansen, and W.J. Berry. 1996. Technical basis and proposal for deriving sediment quality criteria for metals. *Environmental Toxicology and Chemistry* 15:2056-2066.

Bartell, S.M., R.H. Gardner, and R.V. O'Neill. 1992. *Ecological Risk Estimation.* Lewis Publishers, Boca Raton, Florida.

Beyer, W.N. 1990. Evaluating Soil Contamination. United States Department of the Interior, Fish and Wildlife Service, Biological Report 90.

Beyer, W.M., E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *Journal of Wildlife Management* 58:375-382. [see also USEPA 1993a]

Beyer, W.N., G.H. Heinz, and A.W. Redmon-Norwood (editors). 1996. *Environmental Contaminants in Wildlife, Interpreting Tissue Concentrations.* Lewis Publishers, Boca Raton, Florida.

Birge, W.J. 1978. Aquatic Toxicology of Trace Elements of Coal and Flyash. Page 219 in J.H. Thorp and J.W. Gibbons (editors). *Energy and Environmental Stress in Aquatic Systems.* CONF-771114. National Technical Information Service, Springfield, Virginia. [as cited in USEPA 1985]

Bodek, I., W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt (editors). 1988. *Environmental Inorganic Chemistry: Properties, Processes, and Estimation Methods.* Pergamon Press. New York, New York. [SETAC Special Publication]

Chang, L., and L.G. Cockerham. 1994. Toxic Metals in the Environment. Chapter 4 (Pages 109-132) in L.G. Cockerham and B.S. Shane (editors). *Basic Environmental Toxicology.* CRC Press, Boca Raton, Florida.

Cockerham, L.G., and B.S. Shane. 1994. *Basic Environmental Toxicology.* CRC Press, Boca Raton, Florida.

Cody, T.E., M.J. Radike, and D. Warshawsky. 1984. The phytotoxicity of benzo(a)pyrene in the green alga *Selenastrum capricornutum.* Environmental Research 35:122-132.

Dallinger, R., and P.S. Rainbow (editors). 1992. *Ecotoxicology of Metals in Invertebrates.* Lewis Publishers, Boca Raton, Florida. [SETAC Special Publication]

DiToro, D.M. 1985. A particle interaction model of reversible organic chemical sorption. *Chemosphere* 14(10):1503-1538.

D'Itri, F. 1990. The Biomethylation and Cycling of Selected Metals and Metalloids in Aquatic Environments. Chapter 6 (Pages 163-214) <u>in</u> *Sediments: Chemistry and Toxicity of In-Place Pollutants.* Lewis Publishers, Chelsea, Michigan.

Duxbury, C.L., D.G. Dixon, and B.M. Greenberg. 1997. Effects of simulated solar radiation on the bioaccumulation of polycyclic aromatic hydrocarbons by the duckweek *Lemna gibba. Environmental Toxicology and Chemistry* 16:1739-1748.

Edwards, D.A., M.D. Andriot, M.A. Amoruso, A.C. Tummey, C.J. Bevan, A. Tveit, L.A. Hayes, S.H. Youngren, and D.V. Nakles. 1997. *Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons.* Volume 4, Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) Series. Amherst Scientific Publishers, Amherst, Massachusetts.

Efroymson, R.A., M.E. Will, G.W. Suter, II, and A.C. Wooten. 1997a. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.* Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-85/R3.

Efroymson, R.A., M.E. Will, and G.W. Suter, II. 1997b. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.* Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-126/R2.

Eisler, R. 1986. *Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Fish and Wildlife Service. Contaminant Hazard Reviews Report No. 6. Biological Report 85(1.6).

Eisler, R. 1987. *Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Fish and Wildlife Service. Contaminant Hazard Reviews Report No. 11. Biological Report 85(1.11).

Eisler, R. 1988a. *Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Fish and Wildlife Service. Contaminant Hazard Reviews Report No. 12. Biological Report 85(1.12).

Eisler, R. 1988b. *Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Fish and Wildlife Service. Contaminant Hazard Reviews Report No. 14. Biological Report 85(1.14).

Eisler, R. 1989. *Pentachlorophenol Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Fish and Wildlife Service. Contaminant Hazard Reviews Report No. 17. Biological Report 85(1.17).

Eisler, R. 1998a. *Copper Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR--1998.0002.98. [Contaminant Hazard Reviews Report No. 33.]

Eisler, R. 1998b. *Nickel Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* United States Department of the Interior, Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR--1998.0001.98. [Contaminant Hazard Reviews Report No. 34.]

Exponent. 2000. RCRA Facility Investigation, Treated Wood Products Plant, Wiggins, Mississippi. Work Plan. Prepared by Exponent, Bellevue, Washington, for International Paper, Memphis, Tennessee.

Farrington, J.W. 1991. Biogeochemical processes governing exposure and uptake of organic pollutant compounds in aquatic organisms. *Environmental Health Perspectives* 90:75-84.

Fuller, W.H. 1977. *Movement of Selected Metals, Asbestos, and Cyanide in Soil: Applications to Waste Disposal Problems.* United States Environmental Protection Agency, Municipal Environmental Research Laboratory. Cincinnati, Ohio. EPA 600/2-77-020.

Gustafson, J.B., J.G. Tell, and D. Orem. 1997. *Selection of Representative TPH Fractions Based on Fate and Transport Considerations.* Volume 3, Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) Series. Amherst Scientific Publishers, Amherst, Massachusetts.

Harkey, G.A., P.L. Van Hoof, and P.F. Landrum. 1995. Bioavailability of polycyclic aromatic hydrocarbons from a historically contaminated sediment core. *Environmental Toxicology and Chemistry* 14:1551-1560.

Hatzinger, P.B., and M. Alexander. 1995. Effect of aging of chemicals in soil on their biodegradability and extractability. *Environmental Science and Technology* 29(2):537-545.

Hellou, J. 1996. Polycyclic Aromatic Hydrocarbons in Marine Mammals, Finfish, and Molluscs. Pages 229-250 (Chapter 9) in W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood (editors). *Environmental Contaminants in Wildlife, Interpreting Tissue Concentrations.* Lewis Publishers, Boca Raton, Florida.

Holst, L.L., and J.P. Giesy. 1989. Chronic effects of photoinduced toxicity of anthracene on *Daphnia magna* reproduction. *Environmental Toxicology and Chemistry* 8:933-942.

HSDB. 1996. Hazardous Substance Data Bank (HSDB). United States National Library of Medicine. Washington, D.C.

Huang, X., B.J. McConkey, T.S. Babu, and B.M. Greenburg. 1997. Mechanism of photoinduced toxicity of photomodified anthracene to plants: inhibition of photosynthesis in the aquatic higher plant *Lemna gibba* (duckweed). *Environmental Toxicology and Chemistry* 16:1707-1715.

Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese, and W. Basham (compilers/editors). 1997. Environmental Contaminants Encyclopedia. United States Department of the Interior, National Park Service. Water Resources Division, Fort Collins, Colorado. Available online at: www1.nature.nps.gov/toxic/index.html

Jarvinen, A.W., and G.T. Ankley. 1999. *Linkage of Effects to Tissue Residues: Development of a Comprehensive Database for Aquatic Organisms Exposed to Inorganic and Organic Chemicals.* Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, Florida. 364 pp.

Kabata-Pendias, A., and H. Pendias. 1992. *Trace Elements in Soils and Plants.* Second Edition. CRC Press, Boca Raton, Florida.

Karickhoff, S.W., D.S. Brown, and T.A. Scott. Sorption of hydrophobic pollutants on natural sediments. *Water Research* 13:241-248.

Kelsey, J.W., and M. Alexander. 1997. Declining bioavailability and inappropriate estimation of risk of persistent compounds. *Environmental Toxicology and Chemistry* 16:582-585.

Lawrence, J.F., and D.F. Weber. 1984. Determination of polycyclic aromatic hydrocarbons in some Canadian commercial fish, shellfish, and meat products by liquid

chromatography by capillary gas chromatography-mass spectrometry. *Journal of Agricultural Food Chemistry* 32:789-794.

Lindsay, D.M., and J.G. Sanders. 1990. Arsenic uptake and transfer in a simplified estuarine food chain. *Environmental Toxicology and Chemistry* 9:391-395.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19:81-97.

Lyman, W. 1995. Transport and Transformation Processes. Chapter 15 (pages 449-492) in G.M. Rand (editor). *Fundamentals of Aquatic Toxicology.* Second Edition. Taylor & Francis, Washington, D.C.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 1999. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. MacDonald Environmental Services Ltd., Ladysmith, British Columbia, Canada.

Mackenzie, K.M., and D.M. Angevine. 1981. Infertility in mice exposed *in utero* to benzo(a)pyrene. *Biological Reproduction* 24:183-191. [As cited in Sample *et al.* 1996]

McComish, M.F., and J.H. Ong. 1988. Trace Metals. Chapter 7 in I. Bodek, W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt (editors). *Environmental Inorganic Chemistry: Properties, Processes, and Estimation Methods.* Pergamon Press. New York.

MGFC. 1979. Red Creek Float Trip Investigation in Forrest, Stone, George and Jackson Counties. Annual Report, March 1, 1978 – February 28, 1979. D-J Federal Aid Project, Mississippi F-50-1. Mississippi Game and Fish Commission, Jackson, Mississippi.

Neff, J.M. 1985. Polycyclic Aromatic Hydrocarbons. Pages 416-454 in G.M. Rand and S.R. Petrocelli (editors). *Fundamentals of Aquatic Toxicology.* Hemisphere Publishing Corporation, Washington, D.C.

Patton, J.F., and M.P. Dieter. 1980. Effects of petroleum hydrocarbons on hepatic function in the duck. *Comparative Biochemistry and Physiology* 65C:33-36.

Peterson, D. 1994. Calculating the aquatic toxicity of hydrocarbon mixtures. *Chemosphere* 29(12):2493-2506.

Potter, T.L., and K.E. Simmons. 1998. *Composition of Petroleum Mixtures.* Volume 2, Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) Series. Amherst Scientific Publishers, Amherst, Massachusetts.

Rai, D., J. Zachara, A. Schwab, T. Schmidt, D. Girvin, and J. Rogers. 1984. *Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration. Vol. I: A Critical Review.* Report EA-3356 to EPRI by Pacific Northwest Laboratories (Battelle Institute), Richland, Washington. [as cited in McComish and Ong 1988]

Rand, G.M. (editor). 1995. *Fundamentals of Aquatic Toxicology, Effects, Environmental Fate, and Risk Assessment.* Second Edition. Taylor & Francis, Bristol, Pennsylvania.

Rand, G.M., and S.R. Petrocelli (editors). 1985. *Fundamentals of Aquatic Toxicology.* Hemisphere Publishing Corporation, Washington, D.C.

Rao, K.R. (editor). 1978. *Pentachlorophenol: Chemistry, Pharmacology, and Environmental Toxicology.* Plenum Press, New York.

Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision.* Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-86/R3.

Schwetz, J.J., M. Landau, F.E. Dierberg, and R.H. Pierce. 1978. Results of Two-Year Toxicity and Reproduction Studies on Pentachlorophenol in Rats. Pages 301-309 in R. Rao (editor). *Pentachlorophenol: Chemistry, Pharmacology, and Environmental Toxicology.* Plenum Press, New York.

Shephard, B.K., and L.S. McCarty. 1997. Tissue Residue Approaches to Deriving Numerical Sediment Quality Criteria. Interactive Poster Presentation 590. 18th Annual Meeting, Society of Environmental Toxicology and Chemistry (SETAC), San Francisco, California.

Shephard, B.K., and J.W. Webb. 1998. Ecological Toxicity Reference Values for Petroleum Alkane Mixture Toxicity to Aquatic Biota. Poster PMP060. 19th Annual Meeting, Society of Environmental Toxicology and Chemistry (SETAC), Charlotte, North Carolina.

Sirota, G.R., and J.F. Uthe. 1981. Polynuclear Aromatic Hydrocarbon Contamination in Marine Shellfish. Pages 329-341 in M. Cooke and A.J. Dennis (editors). *Chemical Analysis and Biological Fate: Polynuclear Aromatic Hydrocarbons.* Fifth International Symposium. Battelle Press, Columbus, Ohio.

Spacie, A., L.S. McCarty, and G.M. Rand. 1995. Bioaccumulation and Bioavailability in Multiphase Systems. Chapter 16 (pages 493-521) in G.M. Rand (editor). *Fundamentals of Aquatic Toxicology, Effects, Environmental Fate, and Risk Assessment.* Taylor & Francis, Bristol, Pennsylvania.

Spehar, R.L., J.T. Fiandt, R.L. Anderson, and D.L. DeFoe. 1980. Comparative toxicity of arsenic compounds and their accumulation in invertebrates and fish. *Archives of Environmental Contamination and Toxicology* 9:53-63.

Stubblefield, W.A., G.A. Hancock, H.H. Prince, and R.K. Ringer. 1995. Effects of naturally weathered Exxon Valdez crude oil on mallard reproduction. *Environmental Toxicology and Chemistry* 14:1951-1960.

Suter, G.W., II. (editor). 1993. *Ecological Risk Assessment.* Lewis Publishers, Boca Raton, Florida.

Trucco, R.G., F.R. Englehardt, and B. Stacey. 1983. Toxicity, accumulation, and clearance of aromatic hydrocarbons in *Daphnia pulex. Environmental Pollution* (Series A) 31:191-202.

USACE/USEPA. 1997. Environmental Residue-Effects Database (ERED). Dredging Operations Technical Support (DOTS) Program, U.S. Army Corps of Engineers, Waterways Experiment Station, Environmental Laboratory, Vicksburg, Mississippi. Available online at: www.wes.army.mil/el/ered/index.html

USEPA. 1979. *Water-Related Environmental Fate of 129 Priority Pollutants.* United States Environmental Protection Agency, Office of Water, Washington, D.C. EPA/44-/4-79-029a&b.

USEPA. 1985. *Ambient Water Quality Criteria for Arsenic - 1984.* United States Environmental Protection Agency, Office of Water, Washington, D.C. EPA 440/5-84-033.

USEPA. 1980. *Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons.* United States Environmental Protection Agency, Office of Water, Washington, D.C. EPA 440/5-80-069.

USEPA. 1991. *Summary Report on Issues in Ecological Risk Assessment.* United States Environmental Protection Agency, Risk Assessment Forum. Washington, D.C. EPA/625/3-91/018.

USEPA. 1993a. *Wildlife Exposure Factors Handbook.* United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/187a&b (Volumes I and II).

USEPA. 1993b. *Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning.* United States Environmental Protection Agency, Office of Water. EPA-822-R-93-011.

USEPA. 1995. Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment. United States Environmental Protection Agency, Region 4, Office of Technical Services. Atlanta, Georgia. Available online at: www.epa.gov/region4/wastepgs/oftecser/ostguide.htm

USEPA. 1996. *Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod Hyallela azteca and the Midge Chironomus riparius.* United States Environmental Protection Agency, Chicago, Illinois. EPA-905-R96-088.

USEPA. 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final.* United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 540-R-97-006.

USEPA. 1998. *Guidelines for Ecological Risk Assessment.* United States Environmental Protection Agency, Risk Assessment Forum. EPA/630/R-95/002F [see also 63FR93:26845-26924]

USEPA. 1999a. *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Volume One.* Peer Review Draft. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, Region 6. Dallas, Texas. EPA530-D-99-001A.

USEPA. 1999b. *National Recommended Water Quality Criteria -- Correction.* United States Environmental Protection Agency, Office of Water. EPA 822-Z-99-001.

USGS. 1983. *White's Crossing Quadrangle, Stone County, Mississippi, 7.5 Minute Series -- Topographic.* United States Department of the Interior, Geological Survey. Reston, Virginia.

Verscheuren, K. 1982. *Handbook of Environmental Data on Organic Chemicals.* Second Edition. Van Nostrand Reinhold, New York, New York.

Vocke, R.W., K.L. Sears, J.J. O'Toole, and R.B. Wildam.   1980.   Growth responses of selected freshwater algae to trace elements and scrubber ash slurry generated by coal-fired power plants. *Water Research* 14:141-150.

Walk Haydel. 1998. International Paper Wiggins Treated Wood Plant, Wiggins, Mississippi. RCRA Facility Investigation Work Plan. Prepared by Walk Haydel, New Orleans, Louisiana, for International Paper, Memphis, Tennessee.

Weisman, W. (editor).   *Analysis of Petroleum Hydrocarbons in Environmental Media.* Volume 1, Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) Series. Amherst Scientific Publishers, Amherst, Massachusetts.

Williams, P.L.   1982.   Pentachlorophenol, an assessment of the occupational hazard. *American Industrial Hygienists Association Journal* 43:799-810.

TABLES

URS

TABLE 1

SUMMARY OF OCCURRENCE OF CONSTITUENTS OF INTEREST (COIs) AND IDENTIFICATION OF CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN (COPECs) IN SEDIMENTS

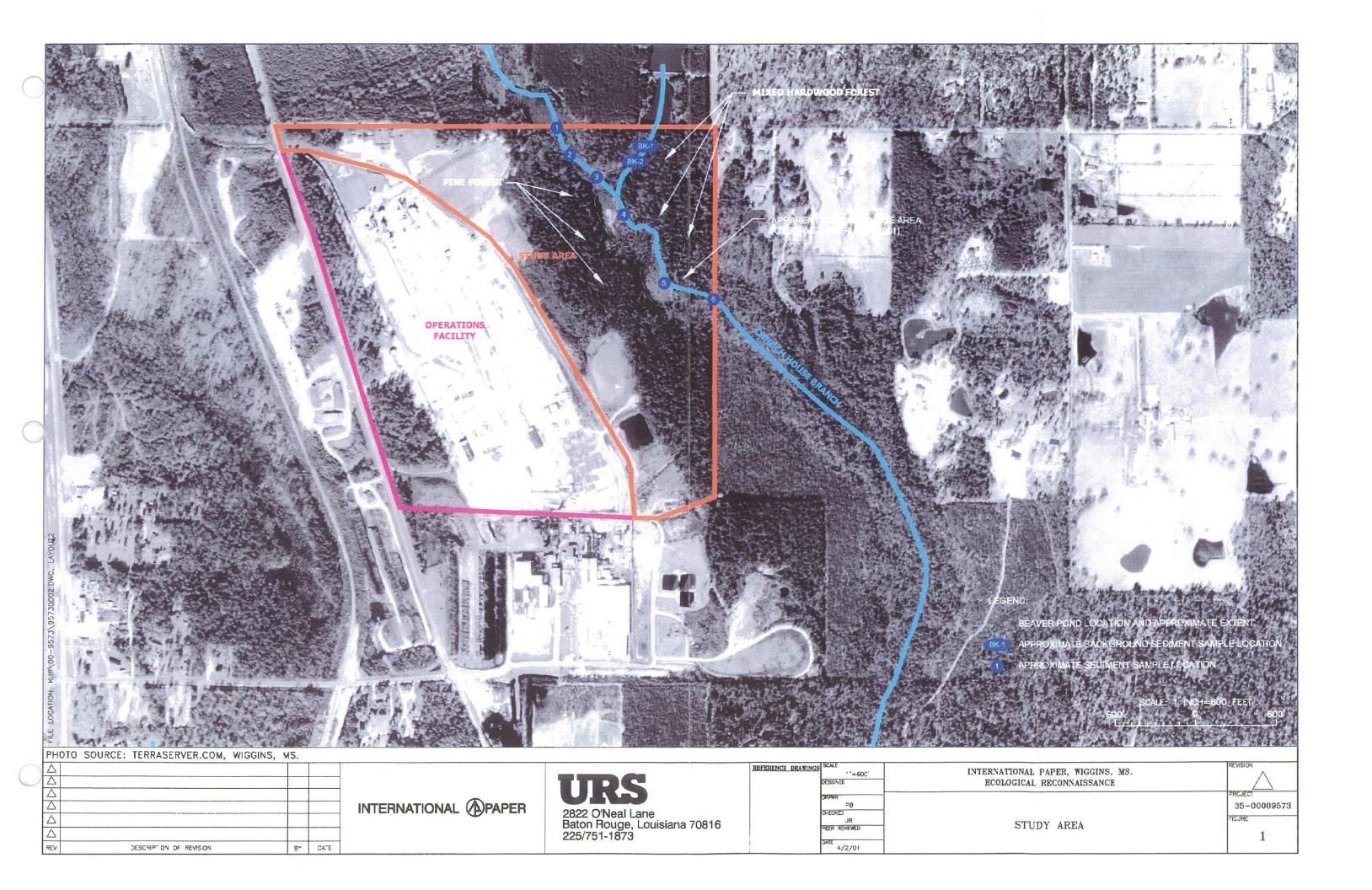| Constituent of Interest	Background			Church House Branch (AOC B)			ESV (mg/kg)[4]		COPEC?[5]
	Freq.[1]	Min.[2]	Max.[3]	Freq.[1]	Min.[2]	Max.[3]	Direct	Indirect	
Inorganics [metals/metalloids] (mg/kg)									
Arsenic (total)	0/2	<0.56	<0.60	6/6	1.50	6.28	9.79	114	No/No
Chromium (total)	2/2	3.34	3.76	6/6	4.67	19.10	43.4	152	No/No
Copper (total)	0/2	<2.82	<2.99	5/6	<2.98	10.00	31.6	97	No/No
Lead (total)	2/2	5.11	5.50	6/6	5.73	19.90	35.8	29	No/No
Nickel (total)	0/2	<2.26	<2.39	1/6	<2.13	2.02	22.7	448	No/No
Petroleum Hydrocarbons (mg/kg-oc)									
PHC as Diesel[6]	2/2	738	7000	6/6	1884	7648	(9060)	NA	No
Polycyclic Aromatic Hydrocarbons [PAHs] (mg/kg)									
2-Methylnaphthalene	0/2	<0.014	<0.014	0/6	<0.014	<0.032	*0.070*	NA	No
Acenaphthene	0/6	<0.014	<0.014	0/6	<0.014	**<0.032**	*0.016*	NA	Uncertain
Acenaphthylene	0/2	<0.014	<0.014	1/6	<0.014	0.035	*0.044*	NA	No
Anthracene	0/2	<0.014	<0.014	3/6	<0.014	**0.144**	0.057	NA	**Yes**
Fluorene	0/2	<0.014	<0.014	0/6	<0.014	<0.032	0.077	NA	No
Naphthalene	0/2	<0.014	<0.014	0/6	<0.014	<0.032	0.035	NA	No
Phenanthrene	0/2	<0.014	<0.014	3/6	<0.014	0.148	0.204	NA	No
Total Low Molecular Weight PAHs	0/2	<0.014	<0.014	3/6	<0.014	**0.391**	<u>0.076</u>	205	**Yes**/No
Benzo(a)anthracene	0/2	<0.014	<0.014	3/6	<0.014	0.075	0.108	NA	No
Benzo(a)pyrene	0/2	<0.014	<0.014	4/6	<0.014	**0.171**	0.150	NA	**Yes**
Benzo(b)fluoranthene	0/2	<0.014	<0.014	4/6	<0.014	**0.264**	<u>0.027</u>	NA	**Yes**
Benzo(g,h,i)perylene	0/2	<0.014	<0.014	1/6	<0.014	**0.078**	<u>0.016</u>	NA	**Yes**
Benzo(k)fluoranthene	0/2	<0.014	<0.014	3/6	<0.014	**0.090**	<u>0.027</u>	NA	**Yes**
Chrysene	0/2	<0.014	<0.014	4/6	<0.014	**0.172**	0.166	NA	**Yes**
Dibenzo(a,h)anthracene	0/2	<0.014	<0.014	0/6	<0.014	<0.032	0.033	NA	No
Fluoranthene	0/2	<0.014	<0.014	4/6	<0.014	0.184	0.423	NA	No

TABLE 1 (continued)

SUMMARY OF OCCURRENCE OF CONSTITUENTS OF INTEREST (COIs) AND IDENTIFICATION OF CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN (COPECs) IN SEDIMENTS
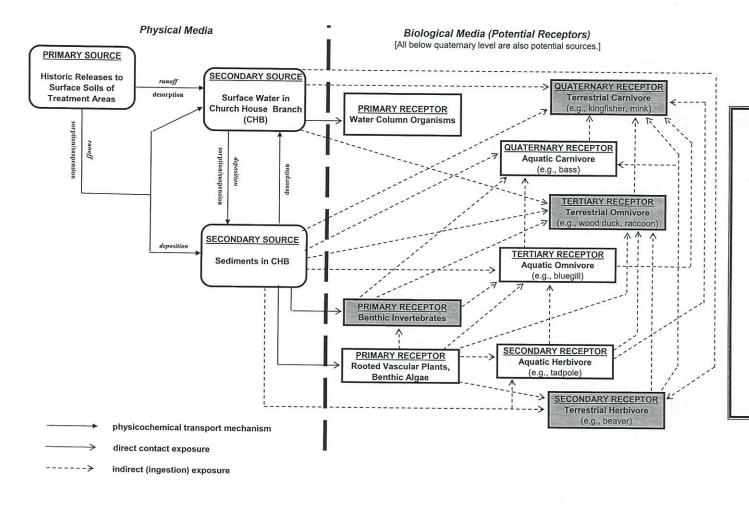
Constituent of Interest	Background			Church House Branch (AOC B)			ESV (mg/kg)[4]		COPEC?[5]
	Freq.[1]	Min.[2]	Max.[3]	Freq.[1]	Min.[2]	Max.[3]	Direct	Indirect	
Indeno(1,2,3-c)pyrene	0/2	<0.014	<0.014	2/6	<0.014	**0.085**	0.017	NA	Yes
Pyrene	0/2	<0.014	<0.014	4/6	<0.014	0.179	0.195	NA	No
Total High Molecular Weight PAHs	0/2	<0.014	<0.014	4/6	<0.014	**1.017**	0.190	3	Yes/No
Total PAHs	0/2	<0.014	<0.014	4/6	<0.014	1.408	1.610	NA	No
Chlorinated Phenols (mg/kg)									
Pentachlorophenol	0/2	<0.070	<0.074	5/6	<0.095	**2.310**	{0.074}	0.02	Yes/Yes

Notes:

1. Frequency; i.e., number of times detected/total number of samples.
2. Minimum; i.e., lowest reported concentration or lowest analytical reporting limit (for constituent/analysis).
3. Maximum; i.e., highest reported concentration or highest analytical reporting limit (for constituent/analysis).
4. ESV = Ecotoxicological Screening Value (sediment "benchmark") as dry weight bulk-sediment concentration or appropriately transformed concentration (see Note 6). Direct-exposure ESVs are formatted to reflect their respective sources as follows: **plain type** - consensus-based threshold effects concentration (TEC) from MacDonald *et al.* (1999); **plain type in parentheses** - organic carbon normalized no-observed-adverse-effects-concentration (NOAEC) for freshwater benthic invertebrates from Shephard and Webb (1998); *italicized type* - effects range - low (ERL) from Long *et al.* (1995); **plain type underlined** - threshold effects level (TEL) from Ingersoll *et al.* (1996; see also USEPA 1996); **plain type in braces** - derived value based on equilibrium partitioning (EqP) approach (USEPA 1993b). Indirect-exposure (ingestion-pathway) ESVs are dry weight bulk-sediment concentrations derived by back calculation from no-observed-adverse-effects-level (NOAEL) doses to sensitive birds or mammals (i.e., the lowest dietary NOAEL among several for each COI). See text for more details and rationale for ESV selection. NA = not available.
5. For each available ESV, a determination is made whether there is a potential risk (toxic response) (Yes/No) or uncertainty remains (due, as in the case of anthracene, non-detection at an analytical reporting limit which exceeds the ESV). A COI is considered to have a potential to elicit adverse effects if its maximum reported concentration equals or exceeds the ESV, and thus becomes a COPEC.
6. The only apparent petroleum hydrocarbons detected in AOC B (and background samples) were "PHC as Diesel", which are herein understood to most closely approximate petroleum alkane mixtures (in the C10-C25 fraction) as discussed in Shephard and Webb (1998). Since the only available ESV is based on EqP and expressed as mg/kg-organic carbon (oc), the background and indicator sediment concentrations are similarly expressed for direct comparison.

FIGURES

MIXED HARDWOOD FOREST

PINE FOREST

STUDY AREA

OPERATIONS
FACILITY

BK-1
BK-2

1
2
3
4
5
6

APPARENT DISCHARGE AREA
(OBSERVED 3FEB 2001)

ZURICH HOUSE BRANCH

LEGEND:

BEAVER POND LOCATION AND APPROXIMATE EXTENT

BK-1 APPROXIMATE BACKGROUND SEDIMENT SAMPLE LOCATION

1 APPROXIMATE SEDIMENT SAMPLE LOCATION

SCALE: 1 INCH=600 FEET

600   0   600'

PHOTO SOURCE: TERRASERVER.COM, WIGGINS, MS.

FILE LOCATION: K:\IP\00-9573\9573000\2.DWG; LAYOUT2

REV   DESCRIPTION OF REVISION   BY   DATE

Figure [ ] Conceptual Ecological Exposure Model

Physical Media

Biological Media (Potential Receptors)
[All below quaternary level are also potential sources.]

PRIMARY SOURCE

Historic Releases to
Surface Soils of
Treatment Areas

runoff
desorption

sorption/suspension
runoff

SECONDARY SOURCE

Surface Water in
Church House Branch
(CHB)

sorption/suspension
deposition
desorption

deposition

SECONDARY SOURCE

Sediments in CHB

PRIMARY RECEPTOR
Water Column Organisms

QUATERNARY RECEPTOR
Terrestrial Carnivore
(e.g., kingfisher, mink)

QUATERNARY RECEPTOR
Aquatic Carnivore
(e.g., bass)

TERTIARY RECEPTOR
Terrestrial Omnivore
(e.g., wood duck, raccoon)

TERTIARY RECEPTOR
Aquatic Omnivore
(e.g., bluegill)

PRIMARY RECEPTOR
Benthic Invertebrates

PRIMARY RECEPTOR
Rooted Vascular Plants,
Benthic Algae

SECONDARY RECEPTOR
Aquatic Herbivore
(e.g., tadpole)

SECONDARY RECEPTOR
Terrestrial Herbivore
(e.g., beaver)

physicochemical transport mechanism

direct contact exposure

- - - - - -> indirect (ingestion) exposure

Measures of Effect

For the screening level ecological risk assessment, potential ecotoxicological effects are evaluated only for direct and indirect exposures attributable to constituents associated with sediments in Church House Branch. Direct exposures attibutable to constituents dissolved or suspended in the overlying water column are not evaluated because surface water has not been analyzed.

Ecological screening values (ESVs) were identified or derived from literature for animals in direct contact with sediments (benthic invertebrates), as well as for selected terrestrial animals ("wildlife") assumed to ingest food items exposed, directly or indirectly, to the sediments. [See text for further details on selection/derivation of ESVs.] Receptor types (groups) for which ESVs are available, indicated by shading in the diagram are those evaluated. Other receptor types (not shaded) are included to: (1) show dietary components contributing to wildlife exposures; and (2) provide a more complete (albeit simplified) representation of potential aquatic exposure pathways.

If an ESV for a particular constituent is equaled or exceeded by the maximum bulk-sediment concentration (or appropriately transformed maximum concentration), a potential for adverse effects due to that constituent is indicated.

APPENDIX A

**INDIRECT EXPOSURE ESTIMATION AND DERIVATION
OF RISK-BASED SEDIMENT SCREENING CONCENTRATIONS
FOR INGESTION-PATHWAY EXPOSURES**

APPENDIX A

Development of Ingestion-Pathway Screening Values

Development of a risk-based bulk-sediment ecological screening value (ESV) for ingestion of a presumptive contaminant entails selection of what are believed to be potentially vulnerable receptors and the most conservative toxicity reference (TRVs) values appropriate to those receptors.

1.0 Receptors of Concern (ROCs)

The receptors of concern (ROCs) selected for this study are the mallard duck (*Anas platyrhynchos*)[1]; belted kingfisher (*Ceryle alcyon*); American beaver (*Castor canadensis*); raccoon (*Procyon lotor*); and mink (*Mustela vison*). As described below, risk-based sediment concentrations (RBCs) were derived for each ROC and all of the inorganic constituents of interest (COIs), Total Low Molecular Weight Polycyclic Hydrocarbons (LPAHs), Total High Molecular Weight PAHs (HPAHs), and Pentachlorophenol (PCP). As discussed in the text, dietary TRVs for "PHC as Diesel" were not available.

2.0 Dietary Exposure Estimates

The TRVs are dietary average daily doses (rates of exposure), expressed as follows (USEPA 1993a):

$$ADD = [IR_{food} * C_{food}] + \{IR_{water} * C_{water}] + [IR_{sed} * C_{sed}] * AUF/BW$$

where,

ADD = Average Daily Dose (mg/kg-BW/day)

IR_{food} = Ingestion rate of food (kg/day)

IR_{water} = Ingestion rate of water (kg/day)

---

[1] Chosen as a surrogate for the wood duck (*Aix sponsa*), which was observed to be common in the study area; the mallard has very similar food habits, and its physiology and sensitivity to various toxicants are much better documented in scientific literature.

IR_{sed} = Ingestion rate of sediment (kg/day)

C_{food} = Concentration of contaminant in food (mg/kg)

[(diet composition$^2_{food1}$ * C_{food1}) + (diet composition$_{food2}$ * C_{food2}) ... food$_n$]/100

C_{water} = Concentration of contaminant in water (mg/L)

C_{sed} = Concentration of contaminant in sediment (mg/kg)

AUF = Area Use Factor (usually a decimal fraction)[3]

BW = Body Weight (kg)

Receptor-specific behavioral and physiological elements (e.g., IR_{food}, BW) for dose estimation are provided in Tables A-1 and A-2. Contaminant concentrations in potential "dietary" items other than sediment are not available in the present study, so they must be estimated via conservative modeling approaches that differ for inorganic *versus* organic constituents.

2.1 Modeled Accumulation of Inorganic Contaminants

The accumulation of inorganic contaminants into vascular plants is predicted using the methods described in BJC (1998a) and RTI (1995). BJC (1998a) developed natural-logarithm based regression equations that describe the uptake of specific inorganic chemicals into vascular plants. The regression equations (Table A-3) are for the whole plant as opposed to particular parts of plants. The general form of the regression is:

Tissue Concentration (mg/kg, dry weight) = $e^{\{a(b \, * \, \ln[\text{soil or sediment- mg/kg}])\}}$

where,

e = the natural logarithm

a = the log intercept for the regression

b = the slope of the regression

ln (soil or sediment) = the natural transformed measured concentration of the inorganic constituent of interest

---

[2] Diet composition is input as percentage of overall diet; the sum of all should equal 100.

[3] AUF is set at 1.0 (100 %) for screening purposes.

Such a form for the predictive equation is intuitive, in that the shape is sigmoid, suggesting that, at low and high soil concentrations, the ratio between the plant concentrations and soil/sediment concentrations is asymptotic.

Not all of the inorganic chemicals have reliable regression equations, and therefore the median of the observed plant factors as reported by BJC (1998a) are used (Table A-3). These uptake factors represent a predicted ratio between soil/sediment[4] concentration and plant tissue concentrations, where:

Tissue Concentration (mg/kg) = UF * soil/sediment-mg/kg

where,

UF   = the uptake factor for the inorganic chemical

Similar uptake regressions have been developed for earthworms, benthic invertebrates, and small mammals for inorganics from soil/sediment (Sample *et al.* 1998a, b; BJC 1998b). When uptake factors are not available from the sources listed above, a theoretical uptake factor -- a bioconcentraion factor (BCF) or biota-sediment accumulation factor (BSAF) is used (Table A-3). For strictly aquatic organisms (algae, invertebrates, fish, and/or tadpoles) the geometric mean of the BCFs obtained from the chemical-specific USEPA ambient water quality criterion document is used. The BCFs from USEPA are based on wet or fresh weight, and were converted to dry weight as described below in Subsection 2.2.5.

2.2   *Modeled Accumulation of Organic Contaminants*

Uptake of organic constituents into plants from soil/sediment is modeled following the fugacity methods presented in Trapp and McFarlane (1995) and Mackay and Paterson (1991). Uptake of organic constituents into invertebrates, secondary and tertiary consumers are also modeled following fugacity methods (Mackay and Paterson 1981; Clark *et al.* 1988; 1990; Mackay and Paterson 1991; Thomann *et al.* 1992; Mackay, *et al.* 1995; Spacie *et al.* 1995) as well as guidance obtained from Belfroid *et al.* (1994) and Belfroid *et al.* (1995).

---

[4] There is sufficient evidence that the uptake of inorganic chemicals by aquatic or hydrophytic plants and upland plants is virtually the same (e.g., Folsom *et al.* 1988), such that the equations for soils are also applicable to sediment.

The relevant physico-chemical properties of the COIs are obtained from the online Hazardous Substances Data Bank (HSDB), as summarized in Table A-4.

2.2.1 Fugacity and Fugacity Capacities

The fugacity approach enables consideration of both chemical-specific and organism-specific attributes (e.g., Clark *et al.* 1988). Fugacity (*F*) is regarded as the "escaping tendency" of a chemical from a particular phase (Mackay and Paterson 1981) with units of pressure (pascals, Pa), and can be related to phase concentrations. For any particular environmental phase (e.g., water, soil, air, or biota) there is a corresponding "fugacity capacity" with units of mol/m^3-Pa which is denoted by a Z value. The relationship between fugacity, fugacity capacity and chemical concentration (C) is defined by:

$$C = ZF$$

Fugacity capacities for a given chemical are calculated for the phases of interest following the methods of Mackay and Paterson (1981; see also Mackay *et al.* 1995). The following calculations require chemical-specific parameters and an assumption of the system temperature, 25°C.

$$Z_{water} = 1 \div H$$

$$Z_{soil} = K_d \times \rho_{soil} \div H$$

$$Z_{air} = 1 \div (R \times T)$$

$$Z_{biota} = lipid \times K_{ow} \times \rho_{biota} \div H$$

where[5]:

H = Henry's Constant

K_d = soil or sediment partitioning coefficient = fraction organic carbon × K_{oc} (partitioning coefficient between water and organic carbon)

ρ_{soil} = bulk density of the soil (g/cm^3)

R = Universal Gas Constant (8.31 Joules-m^3/mol-°K)

T = temperature in degrees Kelvin

lipid = fraction of lipid in the organism

K_{ow} = octanol to water partitioning coefficient

ρ_{biota} = the density of the organism (g/cm^3)

---

[5] Chemical parameters are listed on Table A-4.

The resultant fugacity capacities (Z values) can be used in concert with phase volumes and transport mechanisms (e.g., advection, biotransformation, photolysis, etc) to calculate chemical flux, distributions, mass balance, and persistence (e.g., Mackay and Paterson 1981, 1991). In the risk assessment application here, Z values are used to estimate partitioning between the phases under steady-state conditions assuming no degradation, biotransformation, and unlimited chemical mass (i.e., concentration-based).

Concentration-based modeling differs from strict fugacity approaches through the assumption of unlimited contaminant mass. The application here uses the relationship between fugacity capacities and partitioning coefficients (i.e., Biota-Transfer Factors, BTFs) to predict contaminant concentrations in the tissues and/or diet of the receptors of concern. In order for the relationship between fugacity and partitioning to be functional, in this context, the system is assumed to be at steady-state (Mackay et al. 1995). This is an implicit assumption for this modeling approach[6].

By definition (Mackay et al. 1995), the ratio between Z values of different phases equals the steady-state partitioning coefficient (e.g., the bioconcentration factor; BCF).

For example:

$$Z_{octanol} \div Z_{water} = K_{ow}$$

$$Z_{fish} \div Z_{water} = BCF$$

This approach allows estimation of the partitioning between abiotic media, biological tissue, and ingested materials.

2.2.2 Vascular Plants

---

[6] Unlimited mass assumes that there is sufficient chemical mass to result in steady-state concentrations within all components within the model – abiotic and biotic. This often results in severe over-estimation as kilograms of chemical can be required to produce the predicted concentrations in secondary and tertiary consumers within an ecosystem. Steady state assumes that all compartments within the model (abiotic and biotic) have reached an equilibrium and are unchanging. This is considered a highly conservative assumption for modeling real-world dynamic environments.

A soil or sediment concentration does not solely determine the direct exposure concentration considering uptake of organic contaminants into plants (Bacci *et al*. 1990). For plants there are two pertinent uptake pathways: (1) water taken into the root and transported via the transpiration stream; and (2) uptake from soil-air where soil contaminants have volatilized[7].

A pore-water concentration must be estimated to use this approach in wetland plants. This was accomplished following the equations of Trapp and McFarlane (1995) given soil moisture, total volumetric porosity, and organic carbon content within soil:

$$C_{\text{soil-water}} = C_b \div K_{bw}$$

$$K_{bw} = \rho_b \times K_d + \theta + (\varepsilon - \theta) \times K_{aw}$$

where:

$C_{\text{soil-water}}$ = the soil water concentration

C_b = the bulk soil concentration

K_{bw} = the bulk soil-to-soil water partitioning coefficient

K_d = the soil-to-water partitioning coefficient ($K_d = K_{oc} \times OC$)

$\qquad$ (K_{oc} = the organic carbon-to-water partitioning coefficient and OC = the

$\qquad$ fraction organic carbon in the soil)

ρ_b = soil bulk density (gm/cm^3)

θ = the volumetric water fraction of the soil

ε = the volumetric total porosity of the soil

K_{aw} = the air-to-water partitioning coefficient ($K_{aw} = H \div (R \times T)$)

To calculate a sediment pore water concentration of the constituent, the bulk-sediment concentration is divided by the product of the fraction of organic carbon in sediment and the constituent's K_{oc} (organic carbon-to-water partitioning coefficient):

$$C_{pw} = C_s \div (f_{\text{organic carbon}} \times K_{oc})$$

Given the soil or sediment pore-water concentration of the contaminant, the partitioning between the water and plant root is defined by the root water (W_r) lipid content (L_r), and the K_{ow} of the constituent adjusted by a correction exponent, b, using the default value 0.75 (Trapp and McFarlane 1995). This is to account for the differences between plant lipid and octanol. Finally, the root density compared to water adjusts the partitioning:

---

[7] Volatilization of chemicals into surface air is not considered in this model. Proper estimations would require wind velocities, consideration of spatial volumes (e.g., 1 foot above the ground), and a more complete characterization of the soil surface (i.e., bare ground, vegetated, littered, etc.) such that prospective estimates are not practical.

$$K_{rw} = (W_r + L_r \times K_{ow}^b) \times \rho_r \div \rho_w$$

Combining these equations results in a solution for the root concentration based on the soil-water and soil-air uptake routes:

$$C_{root} = [(W_r + L_r \times K_{ow}^b) \times \rho_r \div \rho_w)] \times [C_b \div (\rho_b \times K_d + \theta + (\varepsilon - \theta) \times K_{aw})]$$

Once within the root tissue the contaminant can be transported via the xylem transpiration stream (Trapp and McFarlane 1995). This translocation, represented below as the transpiration stream concentration factor (TSCF) is defined by the K_{ow} and the soil-water concentration (it is not dependent on the root concentration):

$$TSCF = 0.784 \times exp[-(logK_{ow} - 1.78)^2 \div 2.44]$$

and thus the concentration within the xylem is calculated as:

$$C_{Xy} = TSCF \times C_{soil\text{-}water}$$

The relationship between the concentration in the foliage, fruits, seeds or nuts and the concentration in the xylem is related to the fugacity capacities of the respective phases. The partitioning coefficients are calculated based on the fugacity capacities (Z's):

$$Z_{xylem} = TSCF \div H$$

$$Z_{foliage} = fZ_{air} + fZ_{water} + fZ_{lipid}$$

$$Z_{fruits} = fZ_{air} + fZ_{water} + fZ_{lipid}$$

$$Z_{seeds\ or\ nuts} = fZ_{air} + fZ_{water} + fZ_{lipid}$$

The fugacity capacities of the different plant parts are weighted by the fractions of its constituents: air, water, and lipids (i.e., f's of 18, 80, and 2% respectively for foliage). The partitioning between these plant parts and xylem is then:

$$C_{plant\ part} = (Z_{plant\ part} \div Z_{xylem}) \times C_{xylem}$$

2.2.3   Soil Invertebrates (Including Insects)

Invertebrate detritivores dwelling within or upon the soil are exposed to both soil-water and via the ingestion of soil (Belfroid, *et al.* 1994). Insects, in the context of the model presented, are exposed primarily via the ingestion of plant material and other insects. Given the chitonous exoskeleton, uptake from soil-water is considered insignificant for most insects (Crommentuijn *et al.* 1994). The concentration in soft-bodies invertebrates is calculated as a

combination of uptake from soil pore-water and ingested soil across the gastro-intestinal tract:

$$C_{invertebrate} = [C_b \times (Z_{invertebrate} \div Z_{soil})] + [C_{soil\ water} \times (Z_{invertebrate} \div Z_{soil\ water})]$$

The model assumes a lipid content of 1% in invertebrates as reported by Cobb *et al.* (1995) for earthworms. Z values are calculated as specified above. For insects, only exposure to soil via ingestion of plants or other insects are considered; therefore:

$$C_{herbivorous\ insects} = C_{plant\ foliage} \times (Z_{insect} \div Z_{foliage})$$

$$C_{carnivorous\ insects} = C_{herbivorous\ insect} \times (Z_{insect} \div Z_{herbivorous\ insects})$$

2.2.4 Aquatic Invertebrates

Bioconcentration factors (BCFs) between aquatic organisms and water are based on the lipid content of the species under evaluation and the chemical-specific K_{ow}. There is no correction for the differences between lipids and octanol as the differences are considered insignificant in these organisms (USEPA 1995) and can be derived as follows:

$$BCF = f_{lipid} \times K_{ow}$$

Algae and zooplankton are, in the context of this model, exposed only to surface water, whereas benthic invertebrates are assumed to be infaunal species exposed to sediment pore water. For the purposes of modeling, the surface water concentraion is assumed to be the sediment pore water concentraion divided by ten. This is considered a highly conservative assumption that does not account for any partitioning into suspended solids and/or dissolved organic carbon. Sediment pore-water concentrations are calculated based on the contaminant K_{oc} and the sediment organic carbon content.

$$C_{algae} = BCF \times C_{surface\ water}$$

$$C_{zooplankton} = BCF \times C_{surface\ water} + [(Z_{zooplankton} \div Z_{algae}) \times C_{algae}]$$

$$C_{benthos} = BCF \times C_{pore\ water}$$

Fish, amphibians and certain larger invertebrates (e.g., crayfish) have been identified as potentially playing a significant role within the prospective foodweb of the reservoir. The concentrations within amphibians are expected to be highly influenced by the animals aquatic stage as a tadpole. This stage is essentially herbivorous and the concentration is represented by:

$$C_{\text{fish / amphibian}} = BCF \times C_{\text{surface water}} + [(Z_{\text{fish / amphibian}} \div Z_{\text{algae}}) \times C_{\text{algae}}]$$

Crayfish are essentially epifaunal detritivores who receive direct exposures to surface water, as well ingestion of sediment. Thus the predicted concentration is as follows:

$$C_{\text{crayfish}} = BCF \times C_{\text{surface water}} + [(Z_{\text{crayfish}} \div Z_{\text{sediment}}) \times C_{\text{sediment}}]$$

Three types of fish are incorporated into the modeling scheme, forage fish, trophic level III fish, and trophic level IV fish. Forage fish are essentially herbivores feeding on algae (33% of diet), some benthos (33% of diet – e.g., those invertebrates that migrate up into the water column), and zooplankton (33% of diet). Trophic level III fish in the model feed on 50% benthos and 50% zooplankton while trophic level IV fish feed of 50% forage fish and 50% trophic level III fish. Their respective tissue concentrations are estimated as follows:

$$C_{\text{forage fish}} = BCF \times C_{\text{surface water}} + 0.33 \times [(Z_{\text{forage fish}} \div Z_{\text{algae}}) \times C_{\text{algae}}] + 0.33 \times [(Z_{\text{forage fish}} \div Z_{\text{benthos}}) \times C_{\text{benthos}}] + 0.33 \times [(Z_{\text{forage fish}} \div Z_{\text{zooplankton}}) \times C_{\text{zooplankton}}]$$

$$C_{\text{Trophic level II fish}} = BCF \times C_{\text{surface water}} + 0.5 \times [(Z_{\text{Trophic level III fish}} \div Z_{\text{benthos}}) \times C_{\text{benthos}}] + 0.5 \times [(Z_{\text{Trophic level III fish}} \div Z_{\text{zooplankton}}) \times C_{\text{zooplankton}}]$$

$$C_{\text{Trophic level IV fish}} = BCF \times C_{\text{surface water}} + 0.5 \times [(Z_{\text{Trophic level II fish}} \div Z_{\text{forage fish}}) \times C_{\text{forage fish}}] + 0.5 \times [(Z_{\text{Trophic level IV fish}} \div Z_{\text{Trophic level III fish}}) \times C_{\text{Trophic level III fish}}]$$

2.2.5 Tetrapod Consumers

Modeling of organic contaminant concentrations in secondary consumers begins with the calculation of total ingested mass of constituent based on ingestion rates and concentrations within the ingested materials.

$$M_{\text{abiotic}} = (C_{\text{soil or sediment}} \times IR_{\text{soil or sediment}}) + (C_{\text{water}} \times IR_{\text{water}})$$

$$M_{\text{biotic}} = (C_{\text{dietary item 1}} \times IR \times P_{\text{dietary item 1}}) + (C_{\text{dietary item 2}} \times IR \times P_{\text{dietary item 2}}) + (C_{\text{dietary item n}} \times IR \times P_{\text{dietary item n}})$$

$$M_{\text{total}} = M_{\text{abiotic}} + M_{\text{biotic}}$$

where:

M_{abiotic} = mass of chemical ingested from abiotic items (soil, sediment and water)

M_{biotic} = mass of chemical ingested from biological tissues

M_{total} = total mass of chemical ingested

$C_{dietary\ item\ i}$ = chemical concentration in dietary item

IR = food ingestion rate

$P_{dietary\ item\ i}$ = percentage of diet comprised by dietary item

The contaminant concentration within the diet or more specifically within the gastro-intestinal tract (GIT) of the animal is calculated as:

$$C_{diet} = M_{total} \div [\text{Water Consumed (kg/day)} + \text{Soil or Sediment Consumed (kg/day)} + \text{Food Consumed (kg/day)}]$$

Partitioning between the gut contents of an organism and the organism itself can be estimated via fugacity. The fugacity capacity of the receptor (Z_{biota}) is calculated based on the percent lipid in the animal, the K_{ow} of the contaminant, the density of the animal, assumed to be 1, and the constituent's Henry's constant. The Z_{diet} is calculated by weighting the individual Z values for each component by its percentage (f) of the total material ingested (food + water + soil or sediment). Thus for the wetland community foodweb:

$$Z_{diet} = [(f_{soil\ in\ diet}) \times Z_{soil}] + [(f_{water\ in\ diet}) \times Z_{water}] + [(f_{plants\ in\ diet}) \times Z_{plants}] + [(f_{insects\ in\ diet}) \times Z_{insects}] + [(f_{soil\ invertebrates\ in\ diet}) \times Z_{soil\ invertebrates}] + [(f_{small\ mammals\ in\ diet}) \times Z_{small\ mammals}] + [(f_{birds\ in\ diet}) \times Z_{birds}]$$

and for the limnetic community foodweb:

$$Z_{diet} = [(f_{sediment\ in\ diet}) \times Z_{sediment}] + [(f_{water\ in\ diet}) \times Z_{water}] + [(f_{plants\ in\ diet}) \times Z_{plants}] + [(f_{benthos\ in\ diet}) \times Z_{benthos}] + [(f_{amphibians\ /\ fish\ in\ diet}) \times Z_{amphibians\ /\ fish}] + [(f_{crayfish\ in\ diet}) \times Z_{crayfish}]$$

As previously stated, the ratio of Z values between environmental phases is equal to the partitioning coefficient, thus:

$$C_{animal} = C_{diet} \times (Z_{animal} \div Z_{diet})$$

The resultant tissue concentraions are in wet or fresh weight while the ROC ingestion rates (Table A-3) are in dry weight. The following lipid values and percent moisture contents were used in modeling:

Biological Tissue	Fraction Lipid	Note	Fraction Moisture	Note
Emergent Aquatic Plants	0.50	a	0.82	b
Aquatic Benthic Invertebrates	1.00	c	0.8	b
Forage Fish (Trophic Level II)	3.00	d	0.75	b
Trophic Level III Fish	4.00	d	0.75	b
Trophic Level IV Fish	5.00	d	0.75	b
Algae	1.00	e	0.8	b
Zooplankton	2.00	c	0.8	b
Semi-Aquatic Herbivorous Vertebrates	3.00	e	0.68	b
Semi-Aquatic Omnivorous Vertebrates	3.00	e	0.68	b
Semi-Aquatic Insectivorous Vertebrates	3.00	e	0.68	b
Terrestrial Plant Foliage	1.00	a	0.82	a
Terrestrial Plant Roots	3.00	a	0.75	a
Terrestrial Plant Seeds and Nuts	3.00	a	0.5	a
Terrestrial Plant Fruits	0.50	a	0.85	a
Terrestrial Invertebrate Soil Detritivores	1.00	f	0.84	a
Terrestrial Invertebrate Herbivores	2.00	e	0.69	a
Terrestrial Invertebrate Carnivores	3.00	e	0.61	a
Terrestrial Herbivorous Vertebrates	3.00	e	0.68	a
Terrestrial Omnivorous Vertebrates	3.00	e	0.68	a
Terrestrial Insectivorous Vertebrates	3.00	e	0.68	a

Notes:

a. Trapp and McFarlane (1995).
b. USEPA (1993).
c. Professional judgment and interpretation of the Biota-Sediment Accumulation and Lipid Database. U.S. Army Corps of Engineers; online at http://www.wes.army.mil/el/bsaf/bsaf.html
d. Professional judgment and interpretation of Appendix C in USEPA 1997. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States. Volume 1. National Sediment Quality Survey.* EPA 823-R-97-005.
e. Professional judgment.
f. Cobb *et al.* (1995).

To convert the model wet (fresh) weight concentraions into dry weight concentraions, the model values were divided by the quanty; 1-fraction moisture.

3.0   Dietary Toxicity Reference Values (TRVs)

Table A-5 summarizes what are believed to be the most conservative dietary doses for relevant test organisms[8] based on available scientific literature. To the extent available, a no-observed-adverse-effects-level (NOAEL) and a lowest-observed-adverse-effects-level (LOAEL) were selected (or derived) for each COI/ROC combination. Where only a LOAEL was reported, the corresponding NOAEL was estimated by applying a 'safety' factor of 0.10 (multiplication). Conversely, where only a NOAEL is reported, the LOAEL was estimated by increasing the former by a factor of 10.

4.0   Risk-Based Sediment Concentrations (RBCs)

The sediment RBCs were derived by back-calculation using the equation presented in Subsection 2.2.2 of the SLERA text. Table A-6 summarizes all of the COI/ROC RBS, the lowest of which for each COI was selected for use as the most conservative indirect-exposure ESV for screening [see Table 1 in text].

---

[8] Note that, in most cases, the test organisms used in the bioassays were not of the same species selected as ROCs for this study. Once a dose was selected to represent a particular group of receptors (e.g., birds), the back-calculation used to estimate a risk-based sediment concentration was based on behavioral and physiological exposure assumptions of the actual ROCs (Tables A-1 and A-2).

5.0 References

ATSDR 1990. *Toxicological Profile for Cadmium.* Agency for Toxic Substances and Disease Registry, US Public Health Service.

ATSDR 1993a. *Toxicological Profile for Copper.* Agency for Toxic Substances and Disease Registry, US Public Health Service.

ATSDR 1993b. *Toxicological Profile for Lead.* Agency for Toxic Substances and Disease Registry, US Public Health Service.

ATSDR 1995. *Toxicological Profile for Lead.* Agency for Toxic Substances and Disease Registry, US Public Health Service.

Aulerich, R.J., R.K. Ringer, and M.R. Bleavins. 1982. Effects of supplemental dieatary copper on growth, reproductive performance and kit survival of standard dark mink and the acute toxicity of copper to mink. *Journal of. Animal Science* 55:337-343. [As cited in Sample et al. 1996]

Azar A, H.J. Trochimowicz, M.E. Maxfield. 1973. Review of lead studies in animals carried out at Haskell Laboratory: Two year feeding study and response to hemorrhage study. In D. Barth, A. Berlin, R. Engel *et al.* (editors). *Environmental Health Aspects of Lead: Proceedings, International Symposium,* October 1972, Amsterdam, The Netherlands. Luxembourg: Commission of the European Communities, 199-210. As cited in ATSDR 1993b.

Bacci, E., D. Calamari, C. Gaggi, and M. Vighi. 1990. Bioconcentration of organic chemical vapors in plant leaves: Experimental measurements and correlation. Environmental Science and Technology 24(6):885-889.

Belfroid, A., M. Sikkenk, W. Seinen, K.V. Gestel, and J. Hermens. 1994. The toxicokinetic behavior of chlorobenzenes in earthworm (*Eisenia andrei*) experiments in soil. Environmental Toxicology and Chemistry 13:93-99.

Belfroid, A., M. Van den Berg, W. Seinen, J. Hermens, and K.V. Gestel. 1995. Uptake, bioavailability and elimination of hydrophobic compounds in earthworms (*Eisenia andrei*) in field-contaminated soil. Environmental Toxicology and Chemistry 14:605-612.

BJC. 1998a. *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants.* Prepared by Bechtel Jacobs Company for Oak Ridge National Laboratory. BJC/OR-133.

BJC. 1998b. *Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation.* Prepared by Bechtel Jacobs Company for Oak Ridge National Laboratory. BJC/OR-112.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *Journal of Wildlife Management* 58:375-382.

Beyer, W.N., L.J. Blus, C.J. Henny, and D. Audet. 1997. The role of sediment ingestion in exposing wood ducks to lead. *Ecotoxicology* 6:181-186.

Byron W.R., G.W. Bierbower, J.B. Brouwer, et al. 1967. Pathological changes in rats and dogs from two-year feeding of sodium arsenite or sodium arsenate. *Toxicology and Applied Pharmacology* 10:132-147. [As cited in ATSDR 1993a]

Clark, T., K. Clark, S. Paterson, D. Mackay, and R.J. Norstrom. 1988. Wildlife monitoring, modeling, and fugacity. Environmental Science and Technology 22(2):20.

Cobb, G.P., E.H. Hol, P.W. Allen, J.A. Gagne, and R.J. Kendall. 1995. Uptake, metabolism and toxicity of terbufos in the earthworm (*Lumbriculus terrestris*) exposed to COUNTER®-15G in artificial soils. Environmental Toxicology and Chemistry 14:279-285.

Coburn, D.R., D.W. Metzler, and R. Treichler. 1951. A study of absorption and retention of lead in wild waterfowl in relation to clinical evidence of lead poisoning. *Journal of Wildlife Management*. 15:186-192. [As cited in USEPA 1977]

Crommentuijn, T., C.J.A.M. Doodeman, A. Doorekamp, J.J.C. van der Pol, J.J.M. Bedaux, and C.A.M. van Gestel. 1994. Lethal body concentrations and accumulation patterns determine time-dependent toxicity of cadmium in soil arthropods. Environmental Toxicology and Chemistry 13:1781-1789.

Cupps, P.T. and C.E. Howell. 1949. The effects of feeding supplemental copper to growing fowls. Journal of Animal Sciencie 8:286. [As cited in NAS 1980.]

DeGraaf, R.M., and D.D. Rudis. 1986. *New England Wildlife: Habitat, Natural History, and Distribution*. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experimental Station. General Technical Report NE-108. 491 pp.

Edens, F., W.E. Benton, S.J. Bursian, and G.W. Morgan. 1976. Effect of dietary lead on reproductive performance in Japanese quail, *Coturnix coturnix japonica*. Toxicology and Applied Pharmacology 38:307-314. [As cited in Sample et al. 1996]

Eisler, R. 1988. Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. US Fish and Wildlife Service, Biol. Rep. 85 (1.17).

Eisler, R. 1989. Pentachlorophenol Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. US Fish and Wildlife Service, Biol. Rep. 85 (1.12).

Folsom, B.L., Jr., B.E. Davis, and N.J. Houghton. 1988. *Heavy Metal Uptake by Agronomic Crops and* Cyperus esculentus *Grown on Oxidized and Reduced Soils Contaminated With Metal-Mining Wastes*. Environmental Laboratory, Waterways Experiment Station.

Corps of Engineers. Environmental Effects of Dredging Technical Note EEDP-02-6. Vicksburg, Mississippi.

Gipp, W.F., W.G. Pond, J. Tasker, D. VanCampen, L. Krook, and W.J. Visek. 1973. Influence of level of dietary copper on weight gain, hematology, and liver copper and iron storage in young pigs. Journal of Nutrition. 103:713. [As cited in NAS 1980]

Hamilton, W.J., Jr. 1940. The summer food of minks and raccoons on the Montezume Marsh, New York. Journal of Wildlife Management 4:80-84.

Haseltine, S.D., L. Sileo, D.J. Hoffman, and B.D. Mulhern. 1985. Effects of chromium on reproduction and growth in black ducks. Unpublished; as cited in Sample *et al*. 1996.

Hermayer, K.L., P.E. Stake, and R.L. Shippe. 1977. Evaluation of dietary zinc, cadmium, tin, bismuth and arsenic in hens. Poultry Science 56:1721. [As cited in NAS 1980]

HSDB. Hazardous Substances Data Bank, National Library of Medicine. Online at http://toxnet.nlm.nih.gov.

Ivankovic, S. and R. Preussmann. 1975. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. *Fd. Cosmet. Toxicol*. 13:347-351. As cited in Sample et al. 1996]

Mackay, D., and S. Paterson. 1981. Calculating fugacity. Environmental Science and Technology 15:1006-1014.

Mackay, D., and S. Paterson. 1991. Evaluating the multimedia fate of organic chemicals: A Level III fugacity model. Environmental Science and Technology 25:427-436.

Mackay, D., L.A. Burns, and G.M. Rand. 1995. Fate Modeling. Pages 563-586 (Chapter 18) in G.M. Rand (editor). *Fundamentals of Aquatic Toxicology, Effects, Environmental Fate, and Risk Assessment. Second Edition*. Taylor & Francis, Washington, D.C.

Mackensie, K.M. and D.M. Angevine. 1981. Infertility in mice exposed to benzo[a]pyrene. Biological. Reproduction 24:183-191. [As cited in Sample et al. 1996]

Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. *American Wildlife Plants: A Guide to Wildlife Food Habits*. McGraw-Hill Book Company, New York.

Massie H.R., and V.R. Aiello. 1984. Excessive intake of copper: Influence on longevity and cadmium accumulation in mice. *Mechanisms of Ageing and Development* 26:195-203. [As cited in ATSDR 1990}

Mayo, R.J., S.M. Hauge, H.E. Parker, F.N. Andrews, and C.W. Carrick. 1956. Copper tolerance of young chickens. *Poultry Science* 35:1156. [As cited in NAS 1980]

National Academy of Sciences (NAS). 1980. *Mineral Tolerance of Domestic Animals*. Committee on Animal Nutrition, National Research Council, National Academy of Sciences, Washington, D.C.

Nowak, R.M. 1991. *Walker's Mammals of the World: Fifth Edition*. Volumes I and II. The John Hopkins University Press, Baltimore, MD.

Patton, J.F. and M.P. Dieter. Effects of petroleum hydrocarbons on hepatic function in the duck. *Comparative Biochemistry and Physiology* 65:33-36.

Pershagen, G. and M. Vahter. 1979. Arsenic – a toxicological and epidemiological appraisal. Naturvardverket Rapport. SNV PM 1128, Liber Tryck, Stickholm. 265 pp. [As cited in Eisler 1988]

Richie, H.D., R.W. Luecke, B.V. Baltzer, E.R. Miller, D.E. Ullrey, and J.A. Hoefer. 1963. Copper and zinc interrelationships in the pig. *Journal of Nutrition* 79:117. [As cited in NAS 1980]

Rigdon, R.H. and J. Neal. 1963. Fluorescence of chickens and eggs following the feeding of benzo[a]pyrene crystals. *Texas Reports on Biology and Medicine* 21(4):558-566.

RTI. 1985. Final report (draft): Dose-range finding study of nickel chloride administered to CD rats in the drinking water. Report to Office of Solid Waste Management, U.S. Environmental Protection Agency by Research Triangle Institute. [As cited in ATSDR 1995]

Sample, B.E., and G.W. Suter, II. 1994. *Estimating Exposure of Terrestrial Wildlife to Contaminants*. United States Department of Energy, Office of Environmental Policy and Assistance, Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-125.

Sample, B.E., D.M. Opresko, and G.W. Suter, II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-86/R3.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter, II., and T.L. Ashwood. 1998a. *Development and Validation of Bioaccumulation Models for Earthworms*. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-220.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, and G.W. Suter, II. 1998b. *Development and Validation of Bioaccumulation Models for Small Mammals*. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-219.

Schroeder H.A., M.Kanisawa, D.V. Frost, *et al.* 1968. Germanium, tin and arsenic in rats: Effects on growth, survival, pathological lesions and life span. *Journal of Nutrition* 96:37-45. [As cited in ATSDR 1993]

Silva, M. and J.A. Downing. 1995. *CRC Handbook of Mammalian Body Masses*. CRC Press, Boca Raton, Florida.

Spacie, A., L.S. McCarty, and G.M. Rand. 1995. Bioaccumulation and Bioavailability in Multiphase Systems. Pages 493-521 (Chapter 16) in G.M. Rand (editor). *Fundamentals of Aquatic Toxicology, Effects, Environmental Fate, and Risk Assessment. Second Edition.* Taylor & Francis, Washington, D.C.

Supple, W.C. 1964. Observations on the effect of copper additions to purified turkey diets. *Poultry Science* 43:1599. [As cited in NAS 1980]

Taylor D.H., E.A. Noland, C.M. Brubaker, *et al.* 1982. Low level lead (Pb) exposure produces learning deficits in young rat pups. *Neurobehavioral Toxicology and Teratology* 4:311-314. [As cited in ATSDR 1993b]

Thactcher, C.D., J.B. Meldrum, S.E. Wikse, and W.D. Whitter. 1985. Arsenic toxicosis and suspected chromium toxicosis in a herd of cattle. *Journal of the American Veterinary Medical Association* 187:179-182. [As cited in Eisler 1988]

Thomann, R.V., J.P. Connolly, and T.F. Parkerton. 1992. An equilibrium model or organic chemical accumulation in food webs with sediment interaction. Environmental Toxicology and Chemistry 11:615-629.

USEPA. 1977. *The Short-Term Effects of Lead on Domestic and Wild Animals.* United States Environmental Protection Agency, Office of Research and Development, Corvallis, Oregon, Ecological Research Series. EPA-600/3-77-009.

USEPA. 1984. *Ambient Water Quality Criteria for Arsenic.* United States Environmental Protection Agency. EPA 440/5-84-033.

USEPA. 1985a. *Ambient Water Quality Criteria for Copper.* United States Environmental Protection Agency. EPA 440/5-84-031.

USEPA. 1985b. *Ambient Water Quality Criteria for Lead.* United States Environmental Protection Agency. EPA 440/5-84-027.

USEPA. 1986. *Ambient Water Quality Criteria for Nickel.* United States Environmental Protection Agency. EPA 440/5-86-04.

USEPA. 1993. *Wildlife Exposure Factors Handbook.* United States Environmental Protection Agency, Office of Research and Development, Washington, D.C. EPA/600/R-93/187a&b (Volumes I and II).

USEPA. 1996. *Soil Screening Guidance: Technical Background Document.* United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. Washington, DC. EPA/540/R-95/128.

Weber, C.W. and B.L. Reid. 1968. Nickel toxicity in growing chicks. *Journal of Nutrition* 95:612. As cited in NAS 1980]

Welsh J.J., T.F.X. Collins, T.N. Black, *et al*. 1987. Teratogenic potential of purified pentachlorophenol and pentachloroanisole in subchronically exposed Sprague-Dawley rats. *Food and Cosmetic Toxicology* 25:163-172. [As cited in ATSDR 1994]

BEHAVIORAL AND PHYSIOLOGICAL EXPOSURE ASSUMPTIONS FOR RECEPTORS OF CONCERN (ROCs)

Common Name	Scientific Name	Guild[1]	Area Use (acres)[2]	Body Weight (kg)	Food Ingestion (kg-BW/day)[3]	Water Ingestion (L/day)3	Sediment Ingestion (% of diet)[4]
Mallard (duck)	*Anas platyrhynchos*	Riparian/littoral gleaning omnivore	1334[a]	1.134[a]	0.0632	0.065	3.3[b]
Belted Kingfisher	*Ceryle alcyon*	Water skimming/plunging carnivore	2.54[a]	0.136[a]	0.0159	0.016	3[c]
American Beaver	*Castor canadensis*	Riparian/littoral foraging herbivore	82[d]	17.4[e]	0.697	1.29	10[c]
Raccoon	*Procyon lotor*	Riparian/littoral gleaning omnivore	96[a]	3.91[b]	0.211	0.338	9.4[f]
Mink	*Mustela vison*	Riparian/littoral pursuing carnivore	21.4[a]	1[b]	0.069	0.099	1.3[g]

Notes:
1 Feeding guild, representing broad feeding behavior type and trophic level.
2 The smallest reported home range; regardless of value, for screening purposes the entire diet is assumed to come from AOC B (i.e., the area use factor (AUF) is set at unity in the average daily dose (ADD) calculation; see text).
3 Ingestion rates (foor and water) are taken directly from USEPA (1993) or calculated using appropriate allometric equations provided in USEPA (1993).
4 Sediment ingestion is actually treated (in the ADD calculation) as a rate equivalent to a given percentage of the food ingestion rate.
a USEPA (1993).
b Beyer *et al.* (1997)
c Professional judgement based on the animal's typical feeding behavior and diet.
d Based on average pair density as reported by DeGraaf and Rudis (1986).
e Average for males and females (Silva and Downing 1995)
f Beyer *et al.* (1994).
g Hamilton (1940).

TABLE A-2

ASSUMED DIETARY COMPOSITIONS[1] FOR RECEPTORS OF CONCERN (ROCs)

Common Name	Plants	Insects	Aquatic Invertebrates	Fish	Amphibians	Reptiles	Birds	Mammals	References/Notes
Mallard (duck)	25	25	50						USEPA (1993); plant material is mainly seeds, tubers, stems; aquatic invertebrates are mainly snails, insect larvae, crayfish
Belted Kingfisher			5	90	5				USEPA (1993); primarily forage fish
American Beaver	100								DeGraaf and Rudis (1986)
Raccoon	20	10	45	10	10	5			USEPA (1993); very opportunistic; diet varies with season; plant material is mainly fruits; crayfish and mollusks (where available) are important
Mink			35	40	10	5	5	5	USEPA (1993); fish and shellfish predominate

Notes:

1   Expressed as percent of total diet.

TABLE 3

SUMMARY OF UPTAKE FACTORS FOR INORGANIC CHEMICALS

Metals (mg/kg)		Inorganic Kd	Source	Aquatic BCF	Source	BSAF Regression Slope	Source	BSAF Regression Intercept	Source	BSAF 90th Percentile	Source	Median BSAF	Source	Theoretical BSAF	Source
7440382	Arsenic	2.90E+01	6	2.90E+00	1	0.754	7	-0.292	7	6.90E-01	7	1.43E-01	7	1.00E-01	8
7440473	Chromium (Total)	1.80E+06	6	3.00E+00	2	0.365	7	0.2092	7	4.68E-01	7	1.00E-01	7	1.67E-06	8
7440508	Copper	2.20E+01	2	4.69E+02	3	0.278	7	1.089	7	5.25E+00	7	1.56E+00	7	2.13E+01	8
7439921	Lead	2.80E+05	6	3.31E+02	4	0.801	7	-0.776	7	6.07E-01	7	7.10E-02	7	1.18E-03	8
7440020	Nickel	6.50E+01	6	3.51E+01	5					2.32E+00	7	4.86E-01	7	5.40E-01	8

Metals (mg/kg)		Plant Regression Slope	Source	Plant Regression Intercept	Source	Plant 90th Percentile BCF	Source	Plant Median BCF	Source
7440382	Arsenic	0.564	9	-1.992	9	1.10E+00	9	3.75E-02	9
7440473	Chromium (Total)					8.39E-02	9	4.10E-02	9
7440508	Copper	0.394	9	0.669	9	6.25E-01	9	1.24E-01	9
7439921	Lead	0.561	9	-1.328	9	4.68E-01	9	3.89E-02	9
7440020	Nickel	0.748	9	-2.224	9	1.41E+00	9	1.80E-02	9

Metals (mg/kg)		Herbivore Regression Slope	Source	Herbivore Regression Intercept	Source	Herbivore 90th Percentile BCF	Source	Herbivore Median BCF	Source
7440382	Arsenic	1.1382	10	-5.6531	10	1.60E-02	10	4.20E-03	10
7440473	Chromium (Total)	0.3887	10	-1.35E-01	10	3.09E-01	10	8.84E-02	10
7440508	Copper	0.0675	10	2.04E+00	10	1.29E+00	10	1.09E-01	10
7439921	Lead	0.5181	10	-0.6114	10	1.87E-01	10	5.22E-02	10
7440020	Nickel	0.3766	10	0.3174	10	8.98E-01	10	5.13E-02	10

Metals (mg/kg)		Omnivore Rgeression Slope	Source	Omnivore Regression Intercept	Source	Omnivore 90th Percentile BCF	Source	Omnivore Median BCF	Source
7440382	Arsenic	7.35E-01	10	-4.58E+00	10	1.60E-02	10	4.20E-03	10
7440473	Chromium (Total)	0.7326	10	-1.4945	10	3.49E-01	10	6.99E-02	10
7440508	Copper	0.7326	10	-1.4945	10	5.54E-01	10	1.27E-01	10
7439921	Lead	0.2194	10	0.5669	10	2.86E-01	10	6.59E-02	10
7440020	Nickel	0.478	10	-0.414	10	5.89E-01	10	1.68E-01	10

Metals (mg/kg)		Insectivore Regression Slope	Source	Insectivore Regression Intercept	Source	Invertivore 90th Percentile BCF	Source	Invertivore Median BCF	Source

TABLE 3

SUMMARY OF UPTAKE FACTORS FOR INORGANIC CHEMICALS

7440382	Arsenic	0.8188	11	-4.88471	11	1.30E-03	10	1.30E-03	10
7440473	Chromium (Total)	0.7338	11	-1.4599	11	9.50E-02	10	8.15E-02	10
7440508	Copper	0.1783	10	2.1042	10	1.12E+00	10	7.71E-01	10
7439921	Lead	0.4869	10	0.4819	10	3.39E-01	10	1.60E-01	10
7440020	Nickel	0.5444	10	-0.4266	10	5.78E-01	10	3.64E-01	10

1 USEPA. 1984a. Ambient Water Quality Criteria for Arsenic. United States Environmental Protection Agency. EPA 440/5-84-033.

2 RTI. 1995. Supplemental Technical Support Document for the Hazardous Waste Identification Rule: Risk Assessment for Human and Ecological Receptors. Research Triangle Institute, Center for Environmental Analysis. EPA Contract Number 68-W3-0028.

3 USEPA. 1985a. Ambient Water Quality Criteria for Copper. United States Environmental Protection Agency. EPA 440/5-84-031.

4 USEPA. 1985b. Ambient Water Quality Criteria for Lead. United States Environmental Protection Agency. EPA 440/5-84-027.

5 USEPA. 1986b. Ambient Water Quality Criteria for Nickel. United States Environmental Protection Agency. EPA 440/5-86-04.

6 USEPA. 1996c. Soil Screening Guidance: Technicial Background Document. United States Environmental Protection Agency, Office of Solid Waste and Emergancy Response. Washington, DC. EPA/540/R-95/128.

7 Bechtel Jacobs Company. 1998a. Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation. Oak Ridge National Laboratory. BJC/OR-112.

8 Theoretical BSAF = BCF / Kd

9 Bechtel Jacobs Company. 1998b. Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants. Oak Ridge National Laboratory. BJC/OR-133.

10 Sample, B.E., J.J. Beauchamp, R.A. Efroymson, and G.W. Suter, II. 1998b. Development and Validation of Bioaccumulation Models for Small Mammals. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-219.

11 General Value from Sample, B.E., J.J. Beauchamp, R.A. Efroymson, and G.W. Suter, II. 1998b. Development and Validation of Bioaccumulation Models for Small Mammals. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-219.

PHYSICO-CHEMICAL PROPERTIES OF ORGANIC CONSITUENTS OF INTEREST
[Obtained from Online Hazardous Substances Data Bank (HSDB)]

CAS #	Organic Compounds of Interest	Molecular Wt (g/mol)	Melting Point (0C)	Vapor Pressure (mm of Hg)	Solubility (mg/L) @20-250C	LogKoc	Log Kow	Henry's (atm/m3/mole)	Log BCF
	Low Molecular Weight PAHs								
91587	2-Chloronapthalene	162.61	59.5	7.98E-03	11.7	3.05	NA	3.15E-04	3.63
91576	2-Methylnaphthalene	142.2	34.6	6.81E-02	24.6	3.93	3.86	5.18E-04	2.99
83329	Acenaphthene	154.2	95	1.00E+01	3.9	3.41	3.92	1.55E-04	2.59
208968	Acenaphthylene	152.2	92-93	9.12E-04	16.1	3.25	4.07	1.13E-05	2.11-2.76
120127	Anthracene	178.23	218	2.67E-06	0.0434	5.26	4.45	4.88E-05	3.56
86737	Fluorene	166.21	116-117	3.20E-04	NA	3.95	NA	1.00E-04	3.02-3.35
91203	Naphthalene	128.16	80.2	0.01(kpa)	30	3.26	3.3	NA	1.6-3
85018	Phenanthrene	178.22	101	6.80E-04	1.29	4.36	4.57	1.24E-04	NA
	High Molecular Weight PAHs								
56553	Benzo[a]anthracene	228.29	160	5.00E-09	0.0094	6.00	5.79	8.00E-06	3.40
50328	Benzo[a]pyrene	252.32	179-179.3	5.49E-09	0.0016	6.14	5.97	4.57E-07	2.02
205992	Benzo[b]fluoranthene	252.32	168	5.00E-07	0.00135	6.35	6.6	5.00E-07	3.45
191242	Benzo[ghi]perylene	276.34	277	1.00E-10	0.00026	4.98	6.63	2.66E-07	4.81
207089	Benzo[k]fluoranthene	252.32	217	9.70E-10	0.00076	5.82	6.84	5.84E-07	4.96
218019	Chrysene	228.29	258.2	6.23E-09	0.00189	5.13	5.73	9.90E-07	1.89
53703	Dibenz[a,h]anthracene	278.33	266	1.00E-10	0.000599	6.12	6.5	1.20E-07	3.43
206440	Fluoranthene	202.26	111	9.22E-06	0.26	4.94	5.16	9.45E-06	2.58-4.09
193395	Indeno[1,2,3-c,d]pyrene	276.34	163.6	1.30E-10	0.062	6.82	6.7	3.48E-07	4.00
129000	Pyrene	202.26	151.2	8.92E-05	0.135	5.19	4.88	1.20E-05	2.42
87865	Pentachlorophenol	266.34	174	1.10E-04	14	2.69	5.12	2.45E-08	2.48

Low Molecular Weight PAHs

		High Molecular Weight PAHs	
average logKoc	3.81	average logKoc	5.75
average logKow	4.03	average logKow	6.08
average Henry's	1.08E-04 0.004420029	average Henry's	1.03E-06 4.20599E-05

DIETARY TOXICITY REFRENCE VALUES (TRVs) FOR VERTEBRATE RECEPTORS OF CONCERN

	Arsenic	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Mammals	NOAEL - Non-ruminant Herbivores	Rat	NOAEL	No Adverse Effects	0.7	Schroeder et al. 1968 as cited in ATSDR 1993
	NOAEL - Omnivores	Dog	NOAEL	No Adverse Effects	1.2	Byron et al. 1967 as cited in ATSDR 1993
	NOAEL - Carnivores	Dog	NOAEL	No Adverse Effects	1.2	Byron et al. 1967 as cited in ATSDR 1993
	LOAEL - Non-ruminant Herbivores	Mouse	LOAEL	Reduced Litter Size	0.8	Pershagen and Vahter 1979 as cited in Eisler 1988
	LOAEL - Omnivores	Rat	LOAEL	Survival & Reduced Litter Size	1.4	Pershagen and Vahter 1979 as cited in Eisler 1988
	LOAEL - Carnivores	Cat	LOAEL	Survival	1.5	Pershagen and Vahter 1979 as cited in Eisler 1988
Birds	*Arsenic*	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
	NOAEL - All Species	Cowbird	NOAEL	Clinical Signs	4.7	Thatcher et al. 1985 as cited in Eisler 1988
	LOAEL - All Species	Chicken	LOAEL	Decreased body weight and egg production	6.88	Hermayer et al. 1977 as cited in NAS 1980

	Chromium III	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Mammals	NOAEL - All Species	Rat	NOAEL	Reproduction and longevity	2737	Ivankovic and Preussmann 1975 as cited in Sample et al. 1996
	LOAEL - All Species	Rat	NOAEL *10	Reproduction and longevity	27370	Ivankovic and Preussmann 1975 as cited in Sample et al. 1996
Birds	*Chromium III*	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
	NOAEL - All Species	Black Duck	NOAEL	Reproduction	1	Haseltine et al. (unpubl.) as cited in Sample et al. 1996
	LOAEL - All Species	Black Duck	LOAEL	Reduced Survival	2.7	Haseltine et al. 1985 as cited in Eisler 1986

DIETARY TOXICITY REFRENCE VALUES (TRVs) FOR VERTEBRATE RECEPTORS OF CONCERN

	Copper	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Mammals	NOAEL - Herbivores	Horse	NOAEL	No Adverse Effects (started with 103 to 185 day old animals)	1.96	Cupps and Howell 1949 as cited in NAS 1980
	NOAEL - Omnivores	Swine (A)	NOAEL	No Adevrse Effects (starting with 7-week olds)	6.11	Richie et al. 1963 as cited in NAS 1980
	NOAEL - Carnivores	Mink	NOAEL	Reproduction	11.7	Aulerich et al. 1982 as cited in Sample et al. 1996
	LOAEL - Herbivores	Mouse	LOAEL	Decreased survival	4.2	Massie and Aiello 1984 as cited in ATSDR 1990
	LOAEL - Omnivores	Swine - "young"	LOAEL	Reduced growth	7.25	Gipp et al. 1973 as cited in NAS 1980
	LOAEL - Carnivores	Mink	LOAEL	Reproduction	15.14	Aulerich et al. 1982 as cited in Sample et al. 1996

	Copper	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Birds	NOAEL - All Species	Turkey	NOAEL	Growth and survival	27.5	Supplee 1964 as cited in NAS 1980
	LOAEL - All Species	Chicken (chicks)	LOAEL	Growth, Muscular Dystrophy	29.6	Mayo et al. 1956 as cited in NAS 1980

	Lead	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Mammals	NOAEL - Non-ruminant Herbivores	Dog	NOAEL	No Adverse Effects	12.5	Azar et al. 1973 as cited in ATSDR 1993
	NOAEL - Omnivores	Dog	NOAEL	No Adverse Effects	12.5	Azar et al. 1973 as cited in ATSDR 1993
	NOAEL - Carnivores	Dog	NOAEL	No Adverse Effects	12.5	Azar et al. 1973 as cited in ATSDR 1993
	LOAEL - Non-ruminant Herbivores	Rat	LOAEL	Cortical Development	28	Taylor et al. 1982 as cited in ATSDR 1993
	LOAEL - Omnivores	Rat	LOAEL	Cortical Development	28	Taylor et al. 1982 as cited in ATSDR 1993
	LOAEL - Carnivores	Rat	LOAEL	Cortical Development	28	Taylor et al. 1982 as cited in ATSDR 1993

TABLE A-5

DIETARY TOXICITY REFRENCE VALUES (TRVs) FOR VERTEBRATE RECEPTORS OF CONCERN

	Lead	Representative Test Species	Endpoint	Effect	Dose (mg/kg-BW/day)	Reference
Birds	NOAEL - All Species	Duck	NOAEL	No Effects	6	Coburn at al. 1951 as cited in EPA-600/3-77-009, 1977
	LOAEL - All Species	Japanese Quail	LOAEL	Egg Production, Fertility	11.3	Edens et al. 1976 as cited in Sample et al. 1996

	Nickel	Representative Test Species	Endpoint	Effect	Dose (mg/kg-BW/day)	Reference
Mammals	NOAEL - All Species	Dog	NOAEL	Noa Adverse Effects	12	Browning, Toxic. Indust. Metals 2nd Ed. As cited in HSDB
	LOAEL - All Species	Rat	LOAEL	Decreased Body Weight	20	RTI 1988 as cited in ATSDR 1995

	Nickel	Representative Test Species	Endpoint	Effect	Dose (mg/kg-BW/day)	Reference
Birds	NOAEL - All Species	Chicken	NOAEL	Growth	30.1	Weber and Reid 1968 as cited in NAS 1980
	LOAEL - All Species	Chicken	LOAEL	Decreased growth and N retention	50.2	Weber and Reid 1968 as cited in NAS 1980

	LowMolecular Weight PAHs	Representative Test Species	Endpoint	Effect	Dose (mg/kg-BW/day)	Reference
Mammals	NOAEL - All Species	Mouse	NOAEL (Naphthalene)	Survival, Growth, Organ Weights	53	HSDB, USEPA, NTIS PB90-259821
	LOAEL - All Species	Mouse	LOAEL (Dibenzofuran)	Growth	100	Shepard's Catalog Tetratogenic Agents 1989 as cited in the HSDB

	LowMolecular Weight PAHs	Representative Test Species	Endpoint	Effect	Dose (mg/kg-BW/day)	Reference
Birds	NOAEL - All Species	Mallard	NOAEL	No Signs of Toxicity	212	Patton and Dieter 1980
	LOAEL - All Species	Mallard	NOAEL * 10		2120	Patton and Dieter 1980

	High Molecilar Weight PAHs	Representative Test Species	Endpoint	Effect	Dose (mg/kg-BW/day)	Reference
Mammals	NOAEL - All Species	Mouse	NOAEL (Benzo[a]pyrene)	LOAEL/10	1	Mackenzie & Angvine 1981 as cited in Sample et al. 1996
	LOAEL - All Species	Mouse	LOAEL (Benzo[a]pyrene)	Fertility and Fetal Body Weights	10	Mackenzie & Angvine 1981 as cited in Sample et al. 1996

DIETARY TOXICITY REFRENCE VALUES (TRVs) FOR VERTEBRATE RECEPTORS OF CONCERN

	High Molecilar Weight PAHs	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Birds	NOAEL - All Species	Chicken	NOAEL (Benzo[a]pyrene)	Fertility & Reproduction	4.84	Rigdon, R,H. & J. Neal, Texas Rept. Biol. Med. 21(4):558-566, 1963
	LOAEL - All Species	Chicken	NOAEL *10 (Benzo[a]pyrene)	Fertility & Reproduction	48.4	Rigdon, R,H. & J. Neal, Texas Rept. Biol. Med. 21(4):558-566, 1963

	Pentachlorophenol	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Mammals	NOAEL - All Species	Rat	NOAEL	Reproduction and Development	4	Welsh et al. 1987 as cited in ATSDR 1994
	LOAEL - All Species	Rat	LOAEL	A 10% Decrease in Fetal Body Weights	13	Welsh et al. 1987 as cited in ATSDR 1994

	Pentachlorophenol	*Representative Test Species*	*Endpoint*	*Effect*	*Dose (mg/kg-BW/day)*	*Reference*
Birds	NOAEL - All Species	Snail Kite	LOAEL/10	Survival	1.68	Vermeer et al. 1974 as cited in Eisler 1989
	LOAEL - All Species	Snail Kite	LOAEL	Survival	16.8	Vermeer et al. 1974 as cited in Eisler 1989

SUMMARY OF RISK-BASED BULK-SEDIMENT CONCENTRATIONS[1] FOR INGESTION-PATHWAY EXPOSURE EVALUATIONS

Constituent	Mallard		Kingfisher		Beaver		Raccoon		Mink	
	RBC_{NOAEL}	RBC_{LOAEL}	RBC_{NOAEL}	RBC_{LOAEL}	RBC_{NOAEL}	RBC_{LOAEL}	RBC_{NOAEL}	RBC_{LOAEL}	RBC_{NOAEL}	RBC_{LOAEL}
Arsenic	551	806	925	1354	121	139	**114**	133	237	296
Chromium	**152**	410	285	770	484587	4845871	249428	2494285	661220	6612195
Copper	399	430	109	117	211	451	**97**	115	101	131
Lead	39	74	1704	3209	**29**	65	131	293	3496	7831
Nickel	1338	2232	3010	5019	2479	4132	**448**	746	720	1200
Low Molecular Weight PAHs	1376	13755	426	4260	893	1685	364	687	**205**	387
High Molecular Weight PAHs	24.4	244	7.6	7.6	13.4	134	5.4	53.8	**3**	30
Pentachlorophenol	0.07	0.68	**0.02**	0.21	0.45	1.46	0.18	0.57	0.1	0.31

1. Expressed as milligrams/kilogram (mg/kg); the bold values (lowest for each constituent) were selected for ingestion-pathway ecological screening values (EVS).

Appendix H

Human Health Risk Assessment

Table of Contents

List of Figures

Figures are included at the end of the main text.

List of Tables

Tables are included at the end of the main text.

Attachments

Acronyms and Abbreviations

AOC	area of concern
bgs	below ground surface
CAP	corrective action program
CCA	chromated copper arsenate
CDI	chronic daily intake
CoPC	constituent of potential concern
CSF	carcinogenic slope factor
DAF	dilution-attenuation factor
EPA	U.S. Environmental Protection Agency
HHRA	human health risk assessment
IRIS	Integrated Risk Information System
MDEQ	Mississippi Department of Environmental Quality
PAH	polycyclic aromatic hydrocarbon
PCP	pentachlorophenol
PRG	preliminary remediation goal
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RfD	reference dose
RfDd	dermal reference dose
RME	reasonable maximum exposure
UCL	upper confidence limit
Wiggins facility	International Paper's treated wood products plant in Wiggins, Mississippi

Executive Summary

This human health risk assessment (HHRA) document has been developed to support the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) for International Paper's treated wood products plant in Wiggins, Mississippi (Wiggins) facility. The objective of the baseline HHRA is to quantify human health risks associated with constituents of potential concern (CoPCs) in the absence of any remedial action (i.e., under the no-action alternative). This HHRA is a supplement to the Wiggins RFI, and relies on data collected during that investigation. The assessment was conducted in a manner consistent with U.S. Environmental Protection Agency (EPA) and Mississippi Department of Environmental Quality (MDEQ) guidance and with the 2000 RFI work plan (Exponent 2000).

As indicated in the RFI work plan and in the Wiggins RFI, this investigation focuses on soils and sediments within site boundaries that may have been affected by releases of site-related chemicals. Groundwater was not included in the RFI because of existing groundwater monitoring and control measures, implemented as part of a groundwater Corrective Action Program being conducted under State of Mississippi Hazardous Waste Management Permit No. HW-980-600-084. Furthermore, the vertical extent of site-related chemicals was delineated and was limited to vadose-zone soils. The potential for migration from soil to groundwater was evaluated through comparison of CoPCs with conservative screening values provided by EPA. This comparison indicated limited potential for migration, in light of the typically low concentrations or non-detection of CoPCs in deep soils.

Conservative methods were used to select CoPCs to assure that all potentially significant risks would be evaluated. CoPCs have been identified in surface and subsurface soil and in sediments within the following areas: Treatment Areas 1 and 2 (both surface soil and subsurface soil); Church House Branch sediments; and Site Drainage Ditch Sediments. The HHRA focused on current and hypothetical future conditions that assumed ongoing industrial use of this facility as a work place. In addition, a hypothetical trespasser scenario was evaluated to assess potential risks associated with contact with sediments although the potential for this scenario is considered to be

low given access constraints associated with the ditch and Church House Branch. Inhalation was not considered a significant pathway, based on comparison with conservative preliminary remedial goals derived by EPA. The following exposure pathways were evaluated:

- **Surface soil**: Incidental ingestion, and dermal contact with CoPCs by long-term workers

- **Sediment**: Incidental ingestion and dermal contact with CoPCs by hypothetical trespassers who might gain access to site drainage ditches or to Church House Branch

- **Soil:** Incidental ingestion and dermal contact with CoPCs in soil from 0-17 feet below ground surface (bgs) (i.e., surface to subsurface soil) by construction workers.

The assumptions used to characterize these scenarios are hypothetical. Site entry by trespassers is highly unlikely, given the degree of site security, and the potential for access to offsite areas within Church House Branch is also limited. In addition to consideration of hypothetical exposure pathways, conservative assumptions regarding exposure and toxicity were used to calculate potential risk estimates. Actual contact with site surface soils is likely to be lower than the conservative assumptions applied here, (e.g. an assumed 250 day/year 25 year exposure period for long-term workers). Exposure assumptions and toxicity values used in this HHRA reflect the inherently conservative nature of risk assessments conducted for regulatory purposes.

Potential risk estimates for carcinogens were compared to the range of excess target risk levels (1×10^{-6} to 1×10^{-4}) identified by EPA in the National Contingency Plan, and potential risk estimates for noncarcinogens were compared with a hazard index of 1. For carcinogens, all estimated total cancer risks for both reasonable maximum exposure and typical scenarios were within the 10^{-6} to 10^{-4} target risk range. Specific results for each scenario were as follows:

Excess Cancer Risk Estimates:

- **Long-term workers' contact with surface soils in Treatment Areas 1 and 2.** The current and future long-term worker in Treatment Areas 1 and 2 had the highest *cumulative* risk estimates of 8×10^{-5} and 6×10^{-5}, respectively, due primarily to

pentachlorophenol and arsenic in surface soil in Treatment Area 1 and due to polycyclic aromatic hydrocarbons (PAHs) in surface soil in Treatment Area 2.

- **Construction workers' contact with soil from 0-17 feet bgs.** Risk estimates were well within the acceptable risk range identified by EPA. All estimates for construction worker exposure to soil from 0-17 feet bgs in Treatment Area 1 were less than the 1×10^{-6} risk level identified as the lower end of the acceptable risk range. The cumulative cancer risk estimate for construction worker exposure to soil from 0-17 feet bgs in Treatment Area 2 of 2×10^{-6} just slightly exceeded the lower end of the acceptable risk range.

- **Trespassers' contact with sediments**. Similarly, cancer risk estimates for trespassers were also well within the acceptable risk level identified by EPA.

Hazard Indices:

- No current or future exposure scenarios had hazard indices greater than one for any receptor. This finding suggests that no adverse effects would be expected under the exposure scenarios evaluated.

Given the conservative methods used to assess risks, the finding of no cancer risk estimates greater than the 1×10^{-4} risk level identified by EPA as the upper end of the acceptable risk range suggests that cancer risks are within acceptable levels. In addition, the finding of no hazard indices greater than 1 also suggests that no other adverse effects would be expected.

1 Introduction

This HHRA document has been developed to support the RFI for International Paper's Wiggins facility. The objective of the baseline HHRA is to quantify human health risks associated with CoPCs in the absence of any remedial action (i.e., under the no-action alternative). This HHRA is a supplement to the Wiggins RFI Report and relies on data collected during that investigation. The assessment was conducted in a manner consistent with EPA and MDEQ guidance and with the 2000 RFI Work Plan (Exponent 2000). An ecological risk assessment has also been prepared under separate cover (Appendix G).

The objectives of the Wiggins RFI are to investigate the potential releases of site-related chemicals, characterize the nature and extent of those releases, and identify actual or potential receptors. As indicated in the RFI Work Plan and in the Wiggins RFI Report, this investigation focuses on soils and sediments within site boundaries that may have been affected by releases of site-related chemicals. Pursuant to the approved RFI Work Plan, groundwater is not included because of existing groundwater monitoring and control measures, implemented as part of a groundwater corrective action program (CAP) being conducted under State of Mississippi Hazardous Waste Management Permit No. HW-980-600-084. Thus, this HHRA evaluates only soil and sediments collected during the RFI from the following site areas:

- Vehicle/Equipment Maintenance Area (SWMUs 16 through 19)

- Old Peeler Area (SWMU 20)

- Treatment Area No. 1 (SWMUs 21 through 25, 38, and 39)

- Treatment Area No. 2 (SWMUs 26 through 29, 32, and 33)

- Treated Wood Storage Areas (Area of Concern A)

- Church House Branch (Area of Concern B)

- Site Drainage Ditches (SWMU 37).

The HHRA also draws on information presented in the Wiggins RFI Report regarding site background, hydrology, climate, and demographics. In addition, the Wiggins RFI Work Plan presented the conceptual model for the site (Exponent 2000). This section provides a brief site description and a listing of applicable guidance documents, followed by a description of the organization of this appendix and attachments.

1.1 Site Description

The Wiggins facility is located in Stone County, Mississippi, approximately two miles south of the town of Wiggins, just east of U.S. Highway 49, in Section 31, Township 2 South, Range 11 West, at latitude 30° 51′ 590″ and longitude 89° 10′ 540″. The facility, which is located on 125 acres, has been operating at this location since December 1969. Operations currently conducted at the Wiggins facility involve treating utility poles, pilings, and structural timbers with pentachlorophenol (PCP) and chromated copper arsenate (CCA). Wood-treating operations are conducted in two parallel treatment areas located in the northwestern portion of the facility (Figure H-1). PCP and CCA wood-treating operations are conducted in Treatment Area No. 1, and PCP wood-treating operations are conducted in Treatment Area No. 2. Historical wood-treating operations conducted at Treatment Area No. 2 also used creosote. Vehicle/equipment maintenance activities and pole-peeling activities are conducted in the southern portion of the facility (Figure H-1). Wiggins facility operations currently take place on approximately 85 acres of the site (Figure H-1).

The site is secure, and is guarded 24 hours a day, 7 days a week. It is also located in a relatively unpopulated rural area. Therefore, access to the site by individuals other than employees and their visitors is very limited. At the topographic low point of the site located near Well WC-5, site groundwater is located approximately 15 ft bgs as measured in September 2002. Groundwater beneath the main treatment area is located approximately 60 ft bgs as measured in Well WC-33 in September 2002. Shallow groundwater in the affected (Citronelle) formation is currently being treated and is not used as a drinking water supply; such use is not expected in the future. The deeper (Pascagoula) aquifer is used as a drinking water supply in the site vicinity. However, groundwater monitoring activities have demonstrated that this aquifer has not been

affected by site-related chemicals. Furthermore, the uppermost member of the Pascagoula is characterized as a clayey silt that is has been observed and interpreted to be 13 to 67.5 ft or greater in thickness and is thought to represent a relatively homogeneous, laterally continuous aquitard. Additional details regarding regional and site hydrogeology are provided in the RFI report. Given these hydrogeologic considerations and the current groundwater treatment, exposure via ingestion or direct contact with groundwater is unlikely and is not considered as part of this RFI.

The site has two surface water features: 1) site drainage ditches; and 2) Church House Branch, which begins on the property and extends beyond the site boundary. The site drainage ditches (SWMU 37) consist of approximately 6,800 linear ft of drainage ditches that direct storm water away from the facility. Church House Branch (Area of Concern [AOC] B) is located on the eastern portion of the facility and does not have water flow over the entire year. Church House Branch is also highly overgrown and difficult to access.

1.2 Applicable Guidance

The risk assessment was conducted in accordance with current MDEQ and EPA guidance, including, but not limited to, the following documents:

- Risk Assessment Guidance for Superfund [RAGS]: Volume 1—Human Health Evaluation Manual (Parts A and D) (U.S. EPA 1989, 1991, 1998, 1999a,b)

- Region 4 Human Health Risk Assessment Bulletins—Supplement to RAGS (U.S. EPA 2000) (http://www.epa.gov/region04/waste/oftecser/healtbul.htm)

EPA Region 9 Preliminary Remediation Goals (PRG) table (U.S. EPA 2002a)

- *Risk Assessment Guidance for Superfund—Supplemental Guidance: Dermal Risk Assessment—Interim Guidance* (Final Draft) (U.S. EPA 1999a)

- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (U.S. EPA 1992)

- *Exposure Factors Handbook* (U.S. EPA 1997a)

- *Guidance for Data Usability in Risk Assessment* (U.S. EPA 1990a).

1.3 Organization

Site background information and applicable guidance documents were summarized in Sections 1.1 and 1.2. Sections 2 through 6 describe the results of the four steps recommended in EPA guidance for risk assessment:

- Data evaluation and identification of CoPCs

- Exposure assessment

- Toxicity assessment

- Risk characterization.

An uncertainty assessment is included in the risk characterization to place potential risks in context. The uncertainty assessment discusses HHRA assumptions that may lead to over- or underestimates of potential site risks. The following supporting information is provided in attachments to the HHRA:

Attachment H1, Data Analysis, serves as the basis for selecting CoPCs by summarizing all data reviewed in the HHRA and comparing media concentrations with risk-based concentrations. Specifically, the risk-based concentrations used here are the EPA Region 9 preliminary remediation goals (PRGs). This attachment also shows background concentrations identified for inorganic compounds at the Wiggins facility (as described in Premier [2001]) and presents exposure point concentrations used in the HHRA.

- **Attachment H2, Region 9 Tables of Screening Values**, provides tables of EPA-derived PRGs used in the selection of CoPCs (U.S. EPA 2002a) (as requested by EPA Region 4).

Attachment H3, Risk Characterization Tables, presents results of the risk calculations, including exposure point concentrations, chronic daily intake (CDI) estimates, and risk estimates for each potentially complete exposure pathway.

2 Data Analysis and Identification of Chemicals of Potential Concern

The HHRA uses a conservative screening process to select CoPCs to ensure that any substances that could be of concern are fully evaluated. All available chemical concentration data were reviewed to identify CoPCs in the following media:

- Surface soil

- Subsurface soil

- Sediments

The data screened are those described in the Wiggins RFI (Premier 2001). Table H-1 shows the CoPCs identified for the various media. This section describes the process of screening site data to identify CoPCs. Tables H1-1 through H1-10 provide a summary of Wiggins facility data. These tables present the occurrence, distribution, and selection of CoPCs and provide the following information as specified in U.S. EPA (1998):

- Chemicals detected and undetected in each medium.

- Frequency of detection of chemicals in each medium.

- Range of detected concentrations for each chemical in each medium.

- Background screening values for metals identified for the Wiggins facility (Premier 2001). Additional background values are shown for organic compounds, but, consistent with guidance from EPA Region 4, only inorganic compounds were screened based on background data.

- Screening concentrations (i.e., PRGs), when available, for exposure to residential soil and for migration from soil to groundwater.

Tables H1-11 through H1-16 present exposure point concentrations calculated for each CoPC in each exposure medium and additional supporting documentation consistent with EPA guidance (U.S. EPA 1998). Figures in Premier (2001) show sample locations for data used in the HHRA. The following sections describe how Wiggins facility data were used to identify CoPCs.

Analytical results from Wiggins facility media were initially reviewed to determine a list of substances that may be of concern for human health. The methods used to select CoPCs were intended to ensure that no chemicals detected at levels of potential health concern would be excluded. Concentrations of chemicals in all media were compared with conservative PRGs derived by EPA Region 9, consistent with guidance from EPA Region 4. The EPA PRGs correspond to either a 1×10^{-6} excess cancer risk (for carcinogens) or a hazard quotient of 0.1 (for noncarcinogens), whichever is more stringent (U.S. EPA 2002a). Attachment H2 includes a copy of the EPA Region 9 PRGs used in screening CoPCs. Polycyclic aromatic hydrocarbons (PAHs) for which Region 9 has not developed PRGs were screened using the lower of either Massachusetts or the Mississippi Cleanup Standards for hydrocarbon contaminated soil (Simmons 2001).

Data on site-specific background concentrations of inorganic chemicals were also used in the screening process. As indicated in the RFI Work Plan (Exponent 2000), soil samples were collected from seven locations around the perimeter of the facility to establish background concentrations of CoPCs. These areas were agreed upon with EPA prior to sampling. The locations were within the property boundary and were subject to influences similar to those present at the facility and adjacent to the area (i.e., highway traffic, trash burning, and wood burning), but exclusive of those attributed to operations at the facility (i.e., wood treatment).

Consistent with guidance from EPA Region 4, for inorganic chemicals, the maximum site concentration was compared with two times the mean background concentration. Comparison of site concentrations with samples collected from background locations at the site suggests that site concentrations for some inorganic chemicals are within concentrations typically identified in background soils. However, arsenic and chromium did exceed background in soils at Treatment

Areas 1 and 2. Chemicals identified as CoPCs had maximum concentrations greater than both the PRG and the background concentration.

Data for surface soil, subsurface soil, and sediments were compared with EPA-derived PRGs for residential soil as a conservative means of evaluating direct contact with these media. Use of the PRGs derived for residential soil to screen for CoPCs in these media is highly conservative, because these values are based on daily contact with soil in a residential scenario, whereas exposures to soil/sediments would be restricted to occasional contact during trespassing activities, during working hours, or during short duration construction activities. Such exposures to soil and sediment would be expected to be much less frequent (i.e., at least on order of magnitude) than exposures that a child might receive at a residence.

Surface and subsurface soil data were screened against the EPA Region 9 PRGs for residential soil that integrate exposure to soil through three potential exposure routes: ingestion, inhalation of dust particles or vapors, and dermal contact. In addition, in order to evaluate whether the inhalation pathway should be quantitatively evaluated in the risk assessment, the soil data were screened with EPA PRGs based solely on inhalation of vapors or particulates from soil. For surface soils, the inhalation PRGs applied were those for residential soils, whereas for subsurface soils, the inhalation PRGs applied were those for industrial soils, because of the low likelihood that soil at depth would become airborne (except for construction workers). No chemical concentrations exceeded the inhalation PRGs and therefore the inhalation pathway was not quantified for soils (See Tables H1-1, H1-2, H1-4, H1-5, H1-7, and H1-8).

Consistent with guidance contained in U.S. EPA (1989), data were also evaluated in light of the following considerations:

- Although EPA indicates that chemicals can be excluded based on frequency of detection, no chemicals detected had a low detection frequency and thus none were excluded on this basis.

- If common laboratory chemicals (e.g., acetone, methylene chloride, toluene, phthalate esters) are found at less than 10 times the maximum concentration detected in any blank,

or if other chemicals are found at less than 5 times the maximum concentration detected in any blank, these chemicals can be eliminated. No chemicals were excluded on this basis.

2.1 Soil

The soil data were considered in three groups: surface soils from surface to 1.5 ft, subsurface soils from 5 to 17 ft, and deep soils from 20 to 40 ft. The deep soils were evaluated based only on the potential for migration to groundwater, while other soil data were evaluated based on direct contact pathways.

No chemicals of concern were identified in the following areas:

- Vehicle/Equipment Maintenance Area (SWMUs 16 through 19)

- Treated Wood Storage Areas (AOC A)

The results of the screening of site data for the remaining areas are as follows:

- **Treatment Area No. 1 (SWMUs 21 through 25, 38, and 39)**—Six samples were evaluated for surface soils. Arsenic, 2-methylnapthalene, and PCP were present at concentrations that exceeded the respective PRGs. Fifteen samples were evaluated for subsurface soils, with arsenic, chromium, and PCP exceeding PRGs.

- **Treatment Area No. 2 (SWMUs 26 through 29, 32, and 33)**—In three surface soil samples, five PAH compounds exceeded screening criteria. Arsenic was above the Region 9 PRG, but below background. Thirteen samples were evaluated for subsurface soils, with arsenic, chromium, benzene, PCP, and 9 PAH compounds exceeding the PRGs.

It should be noted that the screening process for soil revealed the fact that several samples had elevated detection limits as the result of dilutions conducted to allow for the accurate quantification of chemicals present at elevated concentrations (e.g., non-PHC as diesel and

pentachlorophenol at GP-14 (0-1.5 feet). These elevated detection limits at times exceeded the screening criteria (i.e., the Region 9 risk-based PRGs). Table H1-17 and H1-18 summarize the samples in Treatment Area 1 and Treatment Area 2, respectively, where this situation occurred.

One method of dealing with this issue is to incorporate the data in the risk evaluations by assuming the detection limit as the representative concentration for the non-detect data. This approach, however, would result in artificially inflated risk estimates specifically for Treatment Area No. 1, since with the exception of indeno(1,2,3-cd-pyrene), the chemicals affected by this situation were non-detect at successively lower detection limits. Therefore, pursuant *to Risk Assessment Guidance for Superfund (RAGS) Part A* (U.S. EPA, 1989), the issue of elevated detection limits that exceed the screening criteria will be qualitatively addressed in the risk characterization and uncertainty section of this report.

2.2 Sediments

Concentrations of chemicals in sediments in the Church House Branch and in the site drainage ditches were also compared with PRGs for residential soil. The findings of this comparison are as follows:

- **Church House Branch (AOC B)**—Six sediment samples were evaluated. Arsenic and one PAH compound exceeded PRGs.

- **Site Drainage Ditches (SWMU 37)**—Twenty sediment samples were evaluated and arsenic, chromium, and six PAH compounds exceeded PRGs.

The screening process for sediments also identified a few samples where the detection limits, diluted to allow for the quantification of chemicals present at elevated concentrations, exceeded corresponding risk-based PRGs. These samples are summarized in Table H1-19, and will also be discussed qualitatively in the uncertainty section of this report.

2.3 Migration Pathways

In addition to evaluation of site data for direct contact pathways (i.e., ingestion and dermal contact), two migration pathways were considered in the screening of site soil data: migration from soil to outdoor air for shallow soil and migration from soil to groundwater for deep soil. As described above, soil concentrations were compared with PRGs for soil derived by EPA, based on inhalation of particulates or volatiles from soil. Consistent with EPA Region 4 guidance, screening values provided by Region 9 were used. For screening surface soils, EPA Region 9 PRGs for residential soils were applied, while subsurface soils were evaluated based on comparison with industrial soils. As indicated previously, because no soil concentrations exceeded the Region 9 PRGs for inhalation, the inhalation pathway was not quantified here.

For evaluating migration to groundwater, the EPA Region 9 soil screening levels (SSLs) for the migration to ground water were compared to site concentrations. The EPA Region 9 documentation indicates that these levels were derived to identify chemical concentrations in soil that have the potential to contaminate ground water under certain conditions. Migration of chemicals from soil to groundwater can be understood as a two-stage process:

1. Release of chemical to soil leachate

2. Transport of the chemical through the underlying soil and aquifer to a receptor.

The SSL methodology considers both of these fate and transport mechanisms and was developed using very conservative assumptions regarding the propensity of a chemical to migrate from soil to groundwater. EPA derived SSLs using two conditions. First, a dilution-attenuation factor (DAF) of 20 (considered as the default value in the Soil Screening Guidance) was used to account for processes that reduce contaminant concentrations in the subsurface soil. Second, EPA derived a SSL applying a DAF of 1, assuming no dilution or attenuation between the source and the receptor well. The SSLs developed under a DAF value of 1 are most appropriate for use at sites where little or no attenuation is expected, e.g., sites with shallow water tables, fractured media, etc.

At the Wiggins facility, the subsurface soil samples were taken between 5 and 17 ft, and the deep subsurface soil was sampled between 20 and 40 ft and no soil samples were in direct proximity to groundwater. Thus, the SSLs with DAF of 1 are not applicable. Therefore, SSLs with DAF of 20 were selected for a preliminary evaluation of the potential for migration to groundwater. In Treatment Area 1 subsurface soils, chromium and PCP were above the SSLs. In the deep subsurface soils only PCP exceeded its SSL. In Treatment Area 2 subsurface soils benzene, PCP, and three PAH compounds were above the SSL and in the deep subsurface soils only PCP exceeded its SSL. PCP was the only compound to exceed the SSL at the Vehicle Maintenance area. No chemicals detected in subsurface soil exceeded SSLs at the Treated Wood Storage Area. A comparison of the SSLs and the maximum detected value for those chemicals is provided in Table H-2.

The findings of a limited number of samples exceeding the conservative SSLs suggests that there is little potential for migration to groundwater.

3 Exposure Assessment

Exposure assessment is the process of identifying human populations that could potentially contact site-related chemicals and estimating the magnitude, frequency, duration, and route(s) of potential exposures. In the HHRA, potential Wiggins facility risks were evaluated in hypothetical current and future workplace scenarios, and in a future trespasser exposure scenario. In addition, potential exposure to soil from 0-17 feet bgs was considered for a construction worker. A residential population was not considered here, given the nature of the area (i.e., current active industrial use), which makes future residential development unlikely. This section describes how these scenarios were selected as a conservative means of estimating current and hypothetical future exposures and potential risks. First, the exposure setting was characterized, and potentially exposed populations were identified (i.e., trespassers and workers). Next, potential exposure pathways were identified, and the methods and assumptions for quantifying exposure were presented. It should be noted that some of the pathways considered are highly unlikely (e.g., trespassing on the site or near the Church House Branch), but were considered here for risk assessment purposes.

3.1 Exposure Setting, Receptor Populations, and Pathways

Given the active industrial use of the Wiggins facility, the site characteristics, current use, and zoning regarding future use, the most likely potential human receptors are onsite workers. Trespassers or workers may also have some limited potential to contact sediments within the Church House Branch or site drainage ditches. Although offsite residents could potentially inhale fugitive dust generated from the site media, screening of site data with PRGs derived to evaluate the inhalation pathway indicated this pathway was not of concern for onsite receptors, and thus airborne exposure would not be expected to be of concern for offsite locations.

The current potential for exposure to CoPCs in soils or sediments is low, because the facility is in active use for the treatment of wood, which typically does not involve workers digging in or

contacting subsurface soil or sediments. The site is also completely fenced and guarded 24 hours per day. Thus, the potential for non-employees to contact CoPCs in site media is quite low or nonexistent. However, the following section identifies the hypothetical pathways evaluated in this assessment for the purposes of determining the need for mitigation of CoPCs in site media.

An exposure pathway is the course a chemical takes from a source to an exposed receptor. Exposure pathways consist of the following four elements: 1) a source; 2) a mechanism of release, retention, or transport of a chemical in a given medium (e.g., air, water, soil); 3) a point of human contact with the medium (i.e., exposure point); and 4) a route of exposure at the point of contact (e.g., incidental ingestion, dermal contact). If any of these elements is missing, the pathway is considered incomplete (i.e., it does not present a means of exposure). Only those exposure pathways judged to be potentially complete are quantified in the HHRA.

This section describes the following hypothetical exposure pathways evaluated in this HHRA:

- **Surface soil**: Incidental ingestion and dermal contact with CoPCs by long-term workers

- **Sediment**: Incidental ingestion and dermal contact with CoPCs by hypothetical trespassers who might gain access to site drainage ditches or to Church House Branch

- **Soil**: Incidental ingestion and dermal contact with CoPCs in soil from 0-17 feet bgs (i.e., surface to subsurface soil) by construction workers.

Table H-3 summarizes the exposure pathways evaluated in the HHRA and is consistent with Table 1 of U.S. EPA (1998).

3.1.1 Current and Future Workers

Current and future long-term onsite worker scenarios were evaluated for surface soils, in which workers are frequently exposed to surface soil via ingestion and dermal contact. Conservative assumptions were used regarding workers' contact with soils. Risks associated with exposure to CoPCs in soil from 0-17 feet bgs (surface to subsurface soil) were evaluated through a current and future construction worker scenario, in which workers contact CoPCs in soil through incidental ingestion and dermal contact.

Pursuant to the approved RFI Work Plan, groundwater was not included in the RFI because of existing groundwater monitoring and control measures implemented as part of a Groundwater Corrective Action Program being conducted under State of Mississippi Hazardous Waste Management Permit No. HW-980-600-084. The vertical extent of site-related chemicals was delineated in the RFI and was determined to be limited to vadose-zone soils. The potential for migration from soil to groundwater was evaluated in Section 2 through comparison of CoPCs with conservative screening values provided by EPA. This comparison indicated limited potential for migration in light of the low concentrations or non-detection of CoPCs in deep soil as well as depth to groundwater (approximately 60 feet below ground surface in the treatment areas). Site groundwater is not used as a source of drinking water supply and there is no potential for groundwater to discharge to surface water. Based on this information, there are no potential exposure points associated with groundwater, and therefore, there are no complete groundwater exposure pathways. Furthermore, groundwater remediation is currently underway. For these reasons, in agreement with EPA, the RFI and this risk assessment have not evaluated groundwater.

3.1.2 Trespassers

Although any trespassing is unlikely to occur given the site security and the location remote from population centers, the most likely receptor within the undeveloped area would be a trespasser who might gain access. Under this hypothetical scenario, ingestion of or dermal contact with sediments is possible. However, exposure would be infrequent in Church House Branch and the site drainage ditches due to difficult access, with even less potential for contact in onsite areas than in offsite areas of the Church House Branch. The most likely human populations to trespass in and around the undeveloped area are adults and older children (i.e., 9–18 years old). Younger children would not be expected to visit these areas, given the limited access.

3.2 *Quantification of Exposure*

In this section, CoPC intakes for chronic exposures are estimated for the exposure pathways identified in the previous section. CoPC intakes are based on estimates of exposure

concentrations at the exposure point (i.e., exposure point concentrations) and on the estimated magnitude of exposure to CoPC-containing media. Exposure estimates for chronic-dose intakes (CDIs) are defined as the mass of a CoPC taken into the body, per unit of body weight, per unit of time. For dermal contact, exposures are expressed as absorbed dose rather than administered dose.

The averaging time used to determine a CDI depends on the type of toxic effect being assessed. For carcinogenic effects, CDIs are calculated by averaging the total cumulative dose over a lifetime. The average lifespan is assumed to be 70 years, based on EPA guidance (U.S. EPA 1991).[1] For assessing noncancer effects, CDIs are calculated by averaging intakes only over the period of exposure. The distinction between these two approaches is based on EPA's currently held opinion that the toxicological mechanisms of action are different for carcinogenic and noncarcinogenic processes (U.S. EPA 1989).

Intakes of CoPCs were estimated using algorithms and assumptions consistent with EPA guidance (e.g., U.S. EPA 1989, 1997a) for the potential exposure pathways described above. Both reasonable maximum exposure (RME) and typical estimates were calculated. EPA describes RME as the highest exposure that is reasonably expected to occur at a site (U.S. EPA 1989). EPA, in the *Final Guidelines for Exposure Assessment*, defines typical exposure as follows:

> *The average [exposure or dose] estimate, used to describe the arithmetic mean, can be approximated by using average values for all the factors making up the exposure or dose equation (57 Fed. Reg. 104: 22888).*

---

[1]   EPA's most recent edition of the Exposure Factors Handbook (U.S. EPA 1997a) recommends use of 75 years for the average value for life expectancy; however, the original 70-year value is used in this risk assessment for consistency among risk assessments, and because some of the carcinogenic slope factors and unit risks (see Section 5) are derived based on a 70-year lifetime, and the difference (error) between the two values is low.

concentrations at the exposure point (i.e., exposure point concentrations) and on the estimated magnitude of exposure to CoPC-containing media. Exposure estimates for chronic-dose intakes (CDIs) are defined as the mass of a CoPC taken into the body, per unit of body weight, per unit of time. For dermal contact, exposures are expressed as absorbed dose rather than administered dose.

The averaging time used to determine a CDI depends on the type of toxic effect being assessed. For carcinogenic effects, CDIs are calculated by averaging the total cumulative dose over a lifetime. The average lifespan is assumed to be 70 years, based on EPA guidance (U.S. EPA 1991).[1] For assessing noncancer effects, CDIs are calculated by averaging intakes only over the period of exposure. The distinction between these two approaches is based on EPA's currently held opinion that the toxicological mechanisms of action are different for carcinogenic and noncarcinogenic processes (U.S. EPA 1989).

Intakes of CoPCs were estimated using algorithms and assumptions consistent with EPA guidance (e.g., U.S. EPA 1989, 1997a) for the potential exposure pathways described above. Both reasonable maximum exposure (RME) and typical estimates were calculated. EPA describes RME as the highest exposure that is reasonably expected to occur at a site (U.S. EPA 1989). EPA, in the *Final Guidelines for Exposure Assessment*, defines typical exposure as follows:

> *The average [exposure or dose] estimate, used to describe the arithmetic mean, can be approximated by using average values for all the factors making up the exposure or dose equation (57 Fed. Reg. 104: 22888).*

---

[1]   EPA's most recent edition of the Exposure Factors Handbook (U.S. EPA 1997a) recommends use of 75 years for the average value for life expectancy; however, the original 70-year value is used in this risk assessment for consistency among risk assessments, and because some of the carcinogenic slope factors and unit risks (see Section 5) are derived based on a 70-year lifetime, and the difference (error) between the two values is low.

The following subsection presents the exposure algorithms and assumptions used to calculate CDIs for each of the exposure pathways listed above, and the methods used to calculate exposure point concentrations for the RME and typical cases.

3.2.1 Exposure Frequency and Duration and Receptor Characteristics

As described above, the most likely human populations to use the area are workers, although a hypothetical trespasser scenario is also evaluated. Worker scenarios considering exposure to surface and subsurface soil were evaluated. The exposure frequency for the long-term worker in both the RME and typical scenarios was 250 days per year, as identified by EPA (U.S. EPA 1997a). The exposure duration for the worker is 25 years for the RME scenario, as identified by EPA (U.S. EPA 1991). For the typical scenario, a 6.6-year duration is applied. This provides a conservative means to evaluate exposure, because 6.6 years was identified as the median amount of time that workers spend in one occupation (U.S. EPA 1997a).

A construction worker scenario was also evaluated to consider hypothetical current or future contact with soil from 0-17 feet bgs (i.e., surface and subsurface soils) in the developed and undeveloped areas. Construction workers were assumed to contact soils for 25 days/year in the RME, or 10 days/year in the typical scenario, over a 2-year construction period. The worker's body weight was assumed to be 70 kg.

A trespasser scenario was considered for evaluation of site sediments assuming the most likely trespassers could be adults and older children (i.e., 9–18 years old). Younger children would not be expected to trespass within the area, given the limited access. Trespassing within the onsite areas is highly unlikely, and any occurrence is expected to be infrequent because of limited access and surrounding industrial development. The offsite reach of Church House Branch is not guarded, but is inaccessible due to location and the degree of vegetation.

Given these considerations, for an RME value, this assessment assumed one visit per week for the three summer months (e.g., when children are out of school) and one visit per month for two additional months in spring and fall, for a total of 14 visits per year. For the typical scenario, the

HHRA assumed an average of one visit per month for the months of May through September, or a total of five visits per year.

Older children are assumed to visit these areas as frequently as adults, but they have a somewhat higher exposure due to their lower body weight (i.e., 49-kg average for ages 9–18, in comparison to 70-kg average for adults). For the RME case, the HHRA assumed that adults might trespass within the area over a period of 30 years, while the typical exposure scenario assumed that both adults and older children might trespass in these areas over a shorter period of 9 years.

3.2.2 Incidental Ingestion of Soils and Sediments

People working or trespassing within the Wiggins facility areas may ingest soils or sediment as a result of direct contact with the hands, followed by hand-to-mouth activity (either inadvertent or associated with eating or smoking). Tables H-4 and H-5 provide exposure assumptions for long-term and construction workers' exposure to soil and Tables H-6 and H-7 provide exposure assumptions for trespassers' exposure to sediments.

Incidental ingestion of soil and sediment was evaluated using EPA guidance for risk assessment regarding soil ingestion. U.S. EPA (1997a) does not provide an upper-bound value for adults and older children. However, U.S. EPA (1991) has identified 100 mg/day as an upper-bound intake rate for adults. Therefore, this value was used as the intake rate for older children and adults in the RME trespasser scenario; and for the adult worker in the RME construction scenario. For the RME long-term worker scenarios, the assumption is made that half of this intake occurs at work, resulting in an RME intake for workers of 50 mg/day (U.S. EPA 1991). Consistent with EPA guidance, the mean value for adults of 50 mg/day was used in the typical trespasser scenario for adults and older children, and in the typical scenario for workers (U.S. EPA 1997a).

3.2.3 Dermal Contact with Soils and Sediments

Dermal exposure was expressed as an absorbed dose by incorporating a chemical-specific dermal absorption factor into the exposure equation. Dermal absorption factors reflect the desorption of the chemical from soil and the absorption of the chemical across the skin and into the

bloodstream (U.S. EPA 1997a). Dermal absorption factors used in the HHRA are reported in Tables H-4 through H-7.

Surface area reflects the amount of skin exposed to a chemical in the exposure scenario. For an adult contact with outdoor soil exposure, U.S. EPA (1997a) recommends using 5,000 cm^2 as a central-tendency estimate and 5,800 cm^2 for an upper-bound estimate. These values represent 25 percent of the total body surface area for adults and were used in the estimates for adult trespassers. Further, EPA recommends deriving similar estimates for children by multiplying the 50th and 95th percentile total body surface areas from Tables 6-6 and 6-7 of the *Exposure Factors Handbook* (U.S. EPA 1997a) by 0.25 for the ages of interest. Thus, the HHRA assumed that 25 percent of the receptor's total body surface area potentially contacts CoPCs in undeveloped-area surface soils and sediments. This resulted in upper-bound and typical surface area estimates of 4,400 cm^2 and 3,600 cm^2, respectively, for children aged 9–18 years.

For workers, the RME value for adult workers of 3,300 cm^2 was applied, based on the average of the 50th percentile of surface area of men and women over age 18, as shown in Tables 6-2 and 6-3 of U.S. EPA (1997a) and as recommended in U.S. EPA (1999a). Consistent with guidance in U.S. EPA (1999a), this value was also conservatively applied in the typical case.

The soil-to-skin adherence factor refers to the amount of soil that remains deposited on the skin after contact. Adherence factors vary by soil type (e.g., moisture content, particle size), by the body part contacting the soil, and by the activity being conducted while in contact with the soil. Adherence values were identified in the EPA's latest dermal guidance (U.S. EPA 1999a) and were applied in this assessment. The values selected are consistent with those identified by EPA Region 9 and used in their screening values (U.S. EPA 2002a). RME and typical adherence factors for adult trespassers were both assumed to be 0.07 mg/cm^2. For older children, RME and typical adherence factors of 0.2 mg/cm^2 were assumed, based on data for children playing in wet soil (U.S. EPA 1999a). For the long-term worker and the construction worker, an adherence value of 0.2 mg/cm^2 was applied in both the RME and the typical case, consistent with recommendations in U.S. EPA (1999a) and as applied in EPA Region 9 screening values (U.S. EPA 2002a).